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THE STRUCTURE AND COMPOSITION OF FOODS

In Press

VOLUME II

VEGETABLES AND FRUITS

In Preparation

VOLUME III

THE STRUCTURE AND COMPOSITION OF FOODS

31

BY

ANDREW L. WINTON, PH.D.

Sometime State and Federal Chemist

AND

KATE BARBER WINTON, PH.D.

Sometime State and Federal Microscopist

VOLUME I

CEREALS, STARCH, OIL SEEDS, NUTS, OILS, FORAGE PLANTS

WITH 274 ILLUSTRATIONS
By the Authors

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE
No.....
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PREFACE

INORGANIC chemistry and vegetable histology ranked from the start as pure sciences; food chemistry and food microscopy developed to a large extent as means to certain practical ends.

The early studies of nutrition led to the framing of a system of analysis in six groups, the results of which have accumulated through several generations. Somewhat later, stimulated by the passage of laws to suppress fraud, more detailed analyses of genuine products were carried out, the results of which serve as a guide in interpreting analyses of suspected articles. Investigation carried out at official and private laboratories in endeavors to widen variety, better quality, increase yield, reduce cost, and prevent waste involved numerous analyses often including determinations of lesser-known constituents.

Supplementing these accumulated data in the applied field are the discoveries of new constituents and of new facts, with regard to constituents previously known to exist, made by a small but devoted group of workers not seeking immediate application but imbued with the idea that fundamental knowledge is an economic asset.

Appreciating the lack of a comprehensive work in the English language, comparable with, yet differing from, the voluminous works in German and French, the writers' task has been partly to collect, select, summarize, and unify, so far as expedient, results on the composition of a great variety of products scattered through numerous journals, and partly to add their own contributions, largely hitherto unpublished, on the gross and microscopic structure of these products.

Special stress is laid on the relation of structure to chemical composition, which is analogous to that of animal anatomy to physiology, one being incomplete without the other.

The products described, chiefly natural or obtained by mechanical separation such as milling or pressing or else by operations involving simple chemical changes, cover a broad geographical range—oriental and occidental, temperate and tropical. Analytical methods and vitamins, adequately treated elsewhere, are not included.

No emphasis is laid on the application of the subject matter in any one particular field; it is presented as general information for any who may have need.

The illustrations have been reproduced from the authors' drawings partly in woodcut by the late Franz X. Matolony of Vienna and partly in copper etching and half-tone by the Powers Photo Engraving Company of New York.

To dedicate the work to any one individual whose friendly guidance one or both of us has experienced would be but to omit mention of others to whom like tribute is due. We venture, however, in this place to venerate the memory of two great histologists, Professor Josef Moeller and Professor Thomas F. Hanausek, and two great chemists, Professor Samuel W. Johnson and Dr. Harvey W. Wiley.

Wilton, Conn.,
January, 1932.

A. L. W.
K. B. W.

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STRUCTURE AND COMPOSITION OF FOODS

STRUCTURE AND COMPOSITION OF FOODS

INTRODUCTION

THE plan followed in this and succeeding volumes is quite simple. The classification is *first* by economic groups as shown on the covers and title pages, *second* by parts—fruits, seeds, leaves, etc., *third* by families, *fourth* by genera, and *fifth* by species. Each natural product heads a chapter. After brief statements of origin, habitat, botanical relationship, and uses, the scientific subject matter is treated under three main heads: (1) macroscopic structure, with due regard to morphology; (2) microscopic structure, which is equivalent in most cases to histology or morphology of the tissues; and (3) chemical composition of the natural product and when practicable of its parts separated mechanically whether in the laboratory or in the factory. Subordinate to (1) and (2) is a section showing the chief structural characters, and subordinate to (3) are often sections showing the composition of manufactured products.

The economic grouping of vegetable products in most cases also is chemical—cereals are distinctly starchy; oil seeds are characterized by the predominance of glycerides; succulent fruits in general are saccharine and acid; most spices owe their value to terpenes or related substances; and members of the beverage group contain stimulating principles classed as alkaloids. Hence the classification is partly chemical and partly botanical, thus better emphasizing what is perhaps the chief mission of the work, namely, the exploiting of the interrelation of structure or optical science to composition or chemical science.

MACROSCOPIC STRUCTURE.—Descriptions are given of gross or lens characters of the parts of each product as separated by simple dissection. This furnishes, so to speak, a chart showing the terrain which has been further explored by microscopists and chemists.

Fruits whether dry or fleshy are made up of *pericarp*, or fruit proper, and seed. The pericarp consists of *epicarp* or outer epiderm, *mesocarp* or middle tissues, which may be dry or fleshy, and *endocarp* or inner coat, which may be a mere membrane or, as in the cocoanut and the stone of the peach, a hard shell.

Seeds consist of (1) the seed coat or *spermoderm*, through which, if not orthotropous, run the raphe and its branches; (2) the *perisperm*, derived from the tissues of the ovule of the flower; (3) the *endosperm* (albumen of the botanist, not albumin of the chemist), and (4) the *embryo* or germ, which in fertile seeds must be fully developed but may nevertheless be minute. The last two are formed within the embryo sac. Perisperm, endosperm, and embryo differ greatly in their relative size and development, and one, two, or all may contain reserve material for the nourishment of the plantlet, furnishing one of the most interesting features of the morphology of seeds. For example, the reserve material of the cereals and buckwheats is largely in the endosperm; of rape and related seeds, also of cotton and of most legumes, in the embryo; of pepper, in the perisperm. In linseed the reserve material is divided between the endosperm and the embryo.

Stems and roots show in cross section several zones: *epiderm*, *cortex*, and *central cylinder* with its fibro-vascular bundles. The meristematic tissues are differently located in exogenous and endogenous plants, as noted in the description of representative members among vegetables and spices. Leaves show between epidermal layers the green tissues that take part in photosynthesis. The parts of flowers are described in every botany. Meat, fish, and eggs also exhibit differentiation evident to the naked eye.

Further morphological details are unfolded in the description of each product. Too great emphasis cannot be laid on the importance of studying each morphological part by itself whenever it is possible to effect a separation. An investigation carried out, for example, on a mixture of starchy endosperm and oily embryo is as unscientific as an analysis of a mixture of a mineral crystal and its matrix.

MICROSCOPIC STRUCTURE.—To chemists and others who are unfamiliar with microtechnique and who are afflicted with a kind of "stage fright," it may be said that the microscope is little more complicated or difficult to operate than the opera-glass. Both employ a focusing screw and require illumination of the object on the stage, in one by substage mirror, in the other by foot-lights. The subject matter, although employing a few terms not in ordinary parlance (but well defined in an unabridged dictionary), does not demand extensive prestudy for its perusal. Naturally one with elementary knowledge is at an advantage, but others with courage may plunge into the subject and soon, by acquiring knowledge here and there, be in possession of all that might be acquired by a systematic course of study.

Definitions.—Brief definitions of the more important tissues together with the reference letters by which they are designated in many of the

cuts may prove helpful to those unfamiliar with the terminology of the histologist.

Cellular Tissues. *Parenchyma* (*p*).—Thin-walled, isodiametric or moderately elongated cells, with walls usually of cellulose, with or without intercellular spaces at the angles. In *spongy parenchyma* the intercellular spaces are conspicuous and the contour of the cells is much distorted.

Collenchyma (*col*).—Cells with conspicuous thickenings at the angles; walls of cellulose or a modification, not lignified.

Sclerenchyma (*scl*).—Cells with lignified, often strongly pitted walls. Includes stone cells (*st*), fibers (*f*), and a great variety of other forms.

Epiderm (*ep*).—The outer (*aep*) and inner (*iep*) tissue layer of organs as for example the spermoderm (seed coat), also the upper and lower tissue layers of leaves.

Epicarp (*epi*) the outer epiderm of the pericarp (fruit coat).

Endocarp (*end*) the innermost layer of the pericarp, often consisting of a dense woody zone.

Cuticle (*c*).—The membranous (not cellular) coating often covering the epiderm, consisting of cutin, a substance related to lignin.

Stomata (*sto*).—The epidermal openings that facilitate assimilation (photosynthesis), respiration, and transpiration.

Water Stomata.—Openings at the ends of nerves through which water is discharged.

Hairs or Trichomes (*t*).—Unicellular or multicellular outgrowths of the epiderm.

Emergences.—Multicellular outgrowths with tissues derived from subepidermal as well as epidermal layers.

Palisade Layer (*pal*).—A layer of elongated cells arranged vertical to the surface of the organ.

Cork (*su*).—Protective tissue of tabular cells in radial rows with suberin as the characteristic constituent of the walls.

Fibro-vascular Bundles (*fv*).—Compound strands of elongated elements consisting of (1) phloem with sieve tubes (*s*), cambiform cells and parenchyma, (2) xylem with pitted (*pi*), reticulated (*ret*), spiral (*sp*), and annular (*an*) vessels, and (3) sheath of bast fibers (*f*). In dicotyledonous plants the bundles form a ring about the stem, whereas in monocotyledonous plants they are distributed irregularly through the pithy tissue; in both cases, however, the bundles are collateral, the phloem and xylem of each being in the same radial row, but in the radial bundles of young roots they are in different radial rows, that is, they alternate in a ring. Concentric bundles with xylem encircling the phloem occur in many rhizomes of monocotyledonous plants and with phloem encircling the xylem are characteristic of ferns.

Cortex.—The layer in stems between the epiderm or cork tissue and the central cylinder with the bundle tissues.

Cell Contents. *Protoplasm.*—The living matter of cells. Among the forms are (1) *cytoplasm*, which is granular or stringy; (2) *cell nucleus*, a round or oval body brought out clearly by special stains; and (3) *plastids* or chromatophores, including *chlorophyl grains* or chloroplasts, the green bodies of leaves, *leucoplasts* or starch formers, and *chromoplasts*, the yellow, orange, or red colored bodies of various organs.

Starch (*am*).—See chapter on Starch.

Sucrose is the only soluble carbohydrate usually present in crystalline form, and this only when deposited by evaporation.

Inulin (*in*) is present in roots, rhizomes, etc. It forms sphæro-crystals with alcohol.

Mucilage (*muc*).—A general term for gelatinizing substances such as gums, pectins, etc.

Aleurone Grains (*al*).—Protein bodies, present in certain oil seeds, consisting of ground substance containing one or more of the following: (1) crystalloids or protein crystals, (2) globoids believed to be phosphates with organic salts, and (3) calcium oxalate crystals.

Tannins, *Fats*, *Fatty Oils*, *Waxes*, *Volatile* or *Essential Oils*, and *Resins* do not occur as definite organized bodies but are recognized by their solubilities or chemical reactions.

Calcium Oxalate occurs often as: (1) single monoclinic crystals, (2) crystal rosettes, (3) raphides or needle-shaped crystals, and (4) crystal sand.

Calcium Carbonate occurs as cystoliths, rarely as crystals.

Silica occurs as rounded bodies in the stegmata of palms and some other plants.

Latex (*l*).—Milky secretions in tubes in various leaves, stems, roots, and fruits.

One with an untrained hand and eye would not be able to verify all the minute details of structure, but he soon would be able to identify the principal tissues and greatly enlarge his horizon. A sharp distinction must be drawn between observing for one's self and reading understandingly. It is believed that the chemist, without attempting any practical microscopic work, will derive much helpful information from even the mere perusal of the text.

A word in explanation and perhaps in defense of some of the terms seems due to histologists. The terms *epidermis*, *hypoderma*, and *spermoderm* have been current. Such a hodgepodge of Greek, Latin, and English is a shock to one's sense of uniformity. In the "Microscopy of Vegetable Foods," *hypoderma* was shortened to the English form *hypoderm*, but courage was then lacking to Anglicize *epidermis*, although precedent was not lacking. In this work the classical endings have been ruthlessly chopped away, and *epiderm*, *hypoderm*, and *spermoderm* adopted. Aside from the point of uniformity, the advantage of being able to form English plurals of words so often used is obvious.

In the cuts, the magnification of 160 diameters has been adhered to whenever practicable, thus making it possible to judge the relative size. This magnification is half that of the original camera lucida drawings made by the writers at the level of the stage with the tube length of 150 mm., No. 7 objective, and No. 0 ocular. Small and large thus apply to relative sizes of the elements at this magnification. Rather than give numerous cumbersome and often worse than useless measurements, a measuring rule accompanies this volume that, applied to cuts magnified 160 diameters, gives the measurement in terms of thousandths of a millimeter (μ).

Reagents.—A long list of reagents seems superfluous, for some are seldom used and others are prepared in various strengths to meet the occasion. The reagents most needed follow:

Acetic Acid.—Equal parts of the glacial acid and water.

Chloral Hydrate.—Dissolve 8 grams of chloral hydrate in 5 cc. of water.

Chlorzinc Iodine.—Dissolve 30 grams of zinc chloride, 5 grams of potassium iodide, and 0.89 gram of iodine in 14 cc. of water. To prevent deterioration keep a few crystals of iodine in the bottle.

Ether.

Ferric Chloride.—A 1 per cent solution.

Glycerin.—Equal parts of glycerin and water are used for mounting.

Grain Alcohol.

Iodine in Potassium Iodide.—Dissolve 0.05 gram of iodine and 0.2 gram of potassium iodide in 15 cc. of water.

Labarraque's Solution, a much-used bleaching agent, may be obtained of any pharmacist, or it may be prepared as follows: thoroughly triturate 75 grams of fresh chlorinated lime (bleaching powder) with 600 cc. of water, added in two or three successive portions, and filter. To the filtrate add a solution of 150 grams of crystallized sodium carbonate in 400 cc. of water, mix thoroughly, warm if the solution gelatinizes, and again filter. Keep in a cool dark place. This solution has largely displaced Javelle water.

Safranin Solution.—A water solution, diluted as needed.

Schultze's Macerating Solution.—Mix a few crystals of potassium chlorate with concentrated nitric acid immediately before using.

Sodium Hydroxide Solution.—Dissolve 5 grams in 100 cc. of water.

Turpentine.—Used for mounting oily substances.

Apparatus.—Although oil immersion objectives, embedding apparatus, microtomes of various types, and other expensive apparatus are invaluable in cytological and embryological work, they are not essential for verifying the descriptions herewith given. Polarizing apparatus is useful, but not indispensable, in the identification of starches. In addition to slides, cover glasses, dropping bottles, watch glasses, and a few simple dissection instruments such as needles, scalpels, and forceps, one modern invention, the Gillette razor blade, deserves special mention, as with its keen edge may be cut thoroughly satisfactory sections of practically every kind of material held in the fingers or between pieces of cork.

CHEMICAL COMPOSITION.—Water, protein, fat, nitrogen-free extract, fiber, and ash form the six so-called crude constituents—more correctly groups—under which fall the numerous actual chemical constituents. The methods employed in determining these crude constituents in essential details have been inherited from the students of human and animal nutrition of the middle of the nineteenth century.

The term "crude" is commonly applied only to the fiber (not present in animal products), but all six constituents are crude, and the

nitrogen-free extract, being obtained by difference and consequently sharing the errors of all the determinations, is crudest of all; yet to add the word " crude " to each or any seems entirely unnecessary, especially as we are far from able to obtain results really worthy of the word " pure." To propose so cumbersome a term as " crude nitrogen-free extract " would be a step in the opposite direction from the adoption of a simplified word suggested below.

Water.—The simplest of all substances in foods is not the simplest to determine. If from mineral substances, where heating from low redness to a white heat is feasible, water is not always readily driven off, how much more serious is the problem where the substance is a complex mixture of organic substances that would be destroyed at a heat far short of redness and may oxidize or suffer other changes even at the temperature of boiling water. Starch holds tenaciously to traces of water, and proteins when in a colloidal condition are not readily dried. On the other hand, some sugars decompose at well below 100° C. and necessitate drying *in vacuo* at 70° C. Presence of other volatile substances such as essential oil adds further to the difficulties. In the earlier analyses, drying was carried out in an open dish in a boiling water oven, but since about 1890, in the United States at least, oxidation has been avoided, and in addition a more complete removal of the moisture has been effected by conducting the drying at 100° C. in a stream of dry hydrogen or *in vacuo*.

Protein.—In the analysis of wheat flour an approximation to the content of protein is secured by washing out the other constituents from the dough in a stream of water, drying the crude gluten, and weighing. In other vegetable products no such rough and ready method is available, and dependence must be placed on the determination of nitrogen and calculation of the protein—or more correctly stated, nitrogenous matter—by the use of a factor, usually 6.25. When it is considered that the range in nitrogen content of vegetable proteins is from less than 15 to at least 19 per cent and that more or less nitrogen exists in non-protein form, the defects of the procedure are obvious. The use of a special factor for each substance, such as 5.7 for wheat flour, adds somewhat to the accuracy, but our knowledge of the nitrogenous constituents of most products is too meager to warrant the adoption of such a special factor.

Stutzer, by his cuprous hydroxide precipitation method, separated the protein nitrogen from the non-protein nitrogen. At the time the method was devised, proteins were known as albuminoids, and the results were calculated by factors in terms of albuminoids and non-albuminoids or amides. At present the unqualified term *protein* is

generally considered to be total nitrogen times 6.25 and is so used in this work, whereas *pure protein* is the designation for protein (albuminoid) nitrogen times the same factor. Wherever the result on protein has been corrected by deduction of non-protein substances such as piperine, caffeine, or theobromine, the facts are stated in a footnote.

During recent years, great progress has been made in the study of proteins. Of particular interest are the products of hydrolysis of individual proteins which appear to be constituents—the so-called building stones—of protein molecules. A large amount of data has also been accumulated on the nitrogen distribution, not only in proteins but also in foods.

For the better understanding of the tables showing the percentages of the hydrolytic products obtained from the various proteins, as given throughout this work, a classified list of the amino acids with formulas has been prepared as follows:

AMINO ACIDS OF FOOD PROTEINS

Aliphatic Series.

Monoamino monobasic acids.

Glycocoll or α-amino-acetic acid, $NH_2 \cdot CH_2 \cdot COOH$.
Alanine or α-amino-proprionic acid, $CH_3 \cdot CHNH_2 \cdot COOH$.
Valine or α-amino-iso-valeric acid, $(CH_3)_2 \cdot CH \cdot CHNH_2 \cdot COOH$.
Leucine or α-amino-iso-butyl-acetic acid, $(CH_3)_2 \cdot CH \cdot CH_2 \cdot CHNH_2 \cdot COOH$.
Glyco-leucine or α-amino-caproic acid, $CH_3 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CHNH_2 \cdot COOH$.
Iso-leucine or α-amino-β-methyl-β-ethyl-proprionic acid $CH_3 \cdot CH_2 \cdot CHCH_3 \cdot CHNH_2 \cdot COOH$.
Serine or α-amino-β-hydroxy-proprionic acid, $CH_2OH \cdot CHNH_2 \cdot COOH$.
Cysteine or α-amino-β-thio-lactic acid, $CH_2SH \cdot CHNH_2 \cdot COOH$.
Cystine or α-diamino-β-dithio-lactic acid, $COOH \cdot CHNH_2 \cdot CH_2 \cdot S \cdot S \cdot CH_2 \cdot CHNH_2 \cdot COOH$.

Monoamino dibasic acids.

Aspartic acid or α-amino-succinic acid, $COOH \cdot CHNH_2 \cdot CH_2 \cdot COOH$.
Glutamic (glutaminic) acid or α-amino-glutaric acid, $COOH \cdot CHNH_2 \cdot CH_2 \cdot CH_2 \cdot COOH$.

Diamino monobasic acids.

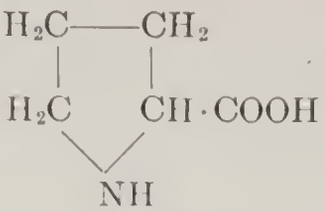
Arginine or α-di-amino-δ-guanido-valeric acid, $NH_2 \cdot CNH \cdot NH \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CHNH_2 \cdot COOH$.
Lysine or α, ϵ-diamino-caproic acid, $NH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CHNH_2 \cdot COOH$.

Isocyclic Series.

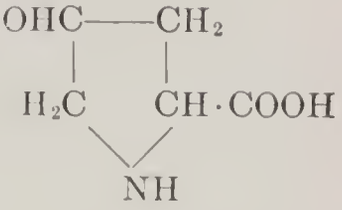
Tyrosine or α-amino-p-hydroxy-phenyl-proprionic acid, $C_6H_4OH \cdot CH_2 \cdot CHNH_2 \cdot COOH$.
Phenylalanine or α-amino-β-phenyl-proprionic acid, $C_6H_5 \cdot CH_2 \cdot CHNH_2 \cdot COOH$

Heterocyclic Series.

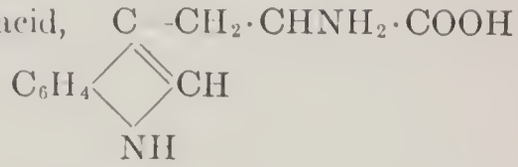
Proline or α-pyrrolidine-carboxylic acid,



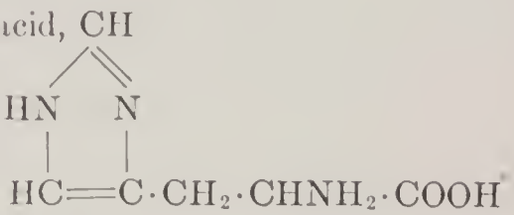
Oxy-proline or oxy-α-pyrrolidine-carboxylic acid,



Tryptophane or α-amino-β-indol-proprionic acid,



Histidine or α-amino-β-imidazol-proprionic acid,



Other Nitrogenous Constituents.—Among the constituents present in minute amount in some foods are *ammonia* and *nitric acid.* These may be satisfactorily determined. Progress has also been made in the determination of *free amino acids, acid amides,* and *peptides* in vegetable products. The *purine bases* classed as alkaloids occur in tea, coffee, and cocoa and also in meat and meat extracts, under which heads they are treated. Results on *creatine* and *creatinine* in meat extracts have also been reported. Of the nitrogenous bases, *choline* and *betaine* in small amount are widely distributed in both vegetable and animal foods.

The nature and occurrence of various nitrogenous substances are briefly noted under the heads of the products in which they are most conspicuously present.

Fat and Oil (Ether Extract).—In the case of most cereals and oil seeds the fat or oil obtained by expression is practically the same as that extracted by ether and consists chiefly of *glycerides* of the fatty acids together with small amounts of free *fatty acids, cholesterol,* and *lecithin.* The fatty acids of the glycerides may consist partly of those low in the series, beginning with butyric, but commonly those with 16 and 18 carbon atoms, both saturated and unsaturated, predominate. Not all the lecithin is usually extracted with ether or is obtained by expression This substance is considered under phosphorus-organic compounds.

The ether extract of green leaves and other organs of a green color contains, in addition to the substances named, chlorophyl, and that of

certain products such as pepper contains alkaloidal substances. Most of the spices and many other odorous substances contain volatile (essential) oil, also related resinous substances.

From these brief statements it is obvious that ether extract differs greatly in its composition and may be quite unlike fat or fatty oil. For our purpose, in the natural foods eaten for their nutritive constituents, not merely for their flavor, the term fat or oil is used to represent ether extract. When *volatile (essential) oil* is associated with non-volatile oil, including resins as well as fatty oil, figures for both are often given. Further discussion of volatile oils and other flavoring substances is reserved for Volume III.

The following fatty acids, combined as glycerides, occur in foods:

FATTY ACIDS OF FOOD FATS

Acetic Series ($C_nH_{2n}O_2$).

Lignoceric, $C_{24}H_{48}O_2$.—Rape and other cruciferous seeds, peanut, soy, sesame, sunflower, maize.

Behenic, $C_{22}H_{44}O_2$.—Rape and other cruciferous seeds.

Arachidic, $C_{20}H_{40}O_2$.—English walnut (trace), pecan (trace), peanut, soy, cottonseed, olive, sesame, sunflower, maize, cocoa.

Stearic, $C_{18}H_{36}O_2$.—Solid fats and most oils.

Palmitic, $C_{16}H_{32}O_2$.—Most fats and many oils.

Myristic, $C_{14}H_{28}O_2$.—Palm kernel, cocoanut, pecan (trace), English walnut (trace), rape and other cruciferous seeds, pistachio, cottonseed, Brazil nut, olive.

Lauric, $C_{12}H_{24}O_2$.—Pine nut, palm kernel, cocoanut, cocoa (?).

Capric, $C_{10}H_{20}O_2$
Caprylic, $C_8H_{16}O_2$
Caproic, $C_6H_{12}O_2$
} Butter, palm kernel, cocoanut.

Butyric, $C_4H_8O_2$.—Butter.

Oleic Series ($C_nH_{2n-2}O_2$).

Erucic, $C_{22}H_{42}O_2$.—Rape and other cruciferous oils, cod-liver oil.

Oleic, $C_{18}H_{34}O_2$.—Oils and most fats.

Linolic Series ($C_nH_{2n-4}O_2$).

Linolic, $C_{18}H_{32}O_2$.—Pine nut, English walnut, pecan, beechnut, hemp, poppy, rape and other cruciferous seeds, almond, peanut, soy, linseed, pili nut, pistachio, cottonseed, Brazil nut, olive, sesame, sunflower, madia, maize, cocoa.

Linolenic Series ($C_nH_{2n-6}O_2$).

Linolenic, $C_{18}H_{30}O_2$.—English walnut, beechnut, hemp, poppy, rape and other cruciferous seeds, soy, linseed, madia.

Isolinolenic.—Hemp, linseed, madia.

Clupanodonic Series ($C_nH_{2n-8}O_2$).

Clupanodonic, $C_{18}H_{28}O_2$.—Marine oils.

Nitrogen-free Extract.—We have seen that both protein and fat are names not of chemical groups but of mixtures of substances alike merely in containing nitrogen and in being soluble in ether respectively. Nitrogen-free extract, taking foods as a whole, merely represents substances that do not fall under the other constituents, together with errors of determination of these constituents. In cereals and other starchy seeds the nitrogen-free extract consists largely of starch, sugars, and dextrins and is often designated carbohydrates, a most unfortunate usage if for no other reason than that the cellulose of fiber is a carbohydrate. With oil seeds containing no starch the nature of the nitrogen-free extract is more indefinite, although sugars are commonly present, and with certain green fodders and non-starchy vegetables a large percentage is of substances yet to be carefully studied.

Nitrogen-free extract has been referred to as the dumping ground. It is a numerical expression of our ignorance and errors. To be sure, it is nitrogen-free, but so are, practically, fat and fiber; it is an extract, but so are fat (ether extract) and the water-soluble ash constituents. Hence neither the term "nitrogen-free" nor "extract," separately or together, is distinctive.

All the above criticisms could be avoided by substituting for the term nitrogen-free extract "undetermined and error." This the writers do not recommend, since nitrogen-free extract has come to have a special significance which in cereal products at least is a close approximation to carbohydrates other than fiber.

A step in the path of simplification would be to abandon the lengthy term nitrogen-free extract in favor of a coined word derived from it. The authors in their notes and conversation have adopted "nifext"—nineteen letters, a hyphen, and a space reduced to six letters—the derivation and meaning of which should be evident even to a foreign reader. By its use every heading in a table giving the six constituents would be a short word. The writers, hesitating to go to the full limit in this work, have employed in table heads the abbreviated form "N-f. ext.," but they hope that this will be a stepping-stone to the coined word nifext.

Carbohydrates.—Sugars, starch, and pentosans have been separately determined in many vegetable products. Here again the results often represent groups though calculated in terms of one constituent. Non-reducing sugars are commonly calculated as sucrose; reducing sugars, as invert (both terms being often used interchangeably); and water-

insoluble, acid-hydrolyzable, also water-insoluble, diastase-hydrolyzable substances as glucose (dextrose), or preferably, in vegetable substances as starch and in animal substances as glycogen. In some instances sugars are calculated as glucose (dextrose) and are so designated.

The following list was compiled from data given by Browne.[1]

CARBOHYDRATES OF FOODS

Monosaccharides.

Dimethyldioses ($C_4H_8O_2$).

Dimethylglycolose, $CH_3 \cdot CHOH \cdot CO \cdot CH_3$.—Occurs in vinegar.

Trioses ($C_3H_6O_3$).

Dioxyacetone, $CH_2OH \cdot CO \cdot CH_2OH$.—Fermentation product.

Oxymethyltetroses ($C_5H_{10}O_5$).

Apiose or β-oxymethyltetrose, $(CH_2OH)_2 \cdot COH \cdot CHOH \cdot CHO$.—A constituent of the glucoside apiin of parsley.

Pentoses ($C_5H_{10}O_5$).

l-Arabinose, $CH_2OH \cdot HCOH \cdot HCOH \cdot HOCH \cdot CHO$.—Formed by hydrolysis of araban.

l-Xylose, $CH_2OH \cdot HOCH \cdot HCOH \cdot HOCH \cdot CHO$.—Formed by hydrolysis of xylan.

d-Ribose, $CH_2OH \cdot HOCH \cdot HOCH \cdot HOCH \cdot CHO$.—Constituent of nucleic acids.

Methylpentoses ($C_6H_{12}O_5$).

Rhamnose, $CH_3 \cdot CHOH \cdot HCOH \cdot HOCH \cdot HOCH \cdot CHO$.—Constituent of glucosides.

Fucose, $CH_3 \cdot CHOH \cdot HOCH \cdot HOCH \cdot HCOH \cdot CHO$.—Formed by hydrolysis of fucosan of seaweeds.

Hexoses ($C_6H_{12}O_6$).

d-Glucose, $CH_2OH \cdot HOCH \cdot HOCH \cdot HCOH \cdot HOCH \cdot CHO$.

d-Mannose, $CH_2OH \cdot HOCH \cdot HOCH \cdot HCOH \cdot HCOH \cdot CHO$.—In plant juices. Formed by hydrolysis of mannan.

d-Galactose, $CH_2OH \cdot HOCH \cdot HCOH \cdot HCOH \cdot HOCH \cdot CHO$.—Constituent of glucosides. Formed by hydrolysis of lactose.

d-Fructose, $CH_2OH \cdot HOCH \cdot HOCH \cdot HCOH \cdot CO \cdot CH_2OH$.

d-Sorbose, $CH_2OH \cdot HCOH \cdot HOCH \cdot HCOH \cdot CO \cdot CH_2OH$.—In fermented juice of *Sorbus domestica*.

Disaccharides ($C_{12}H_{22}O_{11}$).

Sucrose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5$.—In sugar cane, sugar beets, and many natural products.

Maltose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5 + H_2O$.—Formed by the action of malt extract on starch.

[1] Handbook of Sugar Analysis, New York, 1912.

Trehalose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5 + 2H_2O$.—Occurs in mushrooms and other fungi.
Lactose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5 + H_2O$.—The carbohydrate of milk.

Trisaccharides ($C_{18}H_{32}O_{16}$).

Raffinose (melitriose or gossypose), $C_6H_{11}O_5 \cdot O \cdot C_6H_{10}O_4 \cdot O \cdot C_6H_{11}O_5 + 5H_2O$.—Occurs in beet juice and cottonseed.

Polysaccharides.—To this group belong *xylan* and *araban*, both assigned tentatively the formula $(C_6H_8O_4)_n$, which are widely distributed in nature and are the mother substances of the pentoses xylose and arabinose, respectively, also *starch* (see chapter on Starch), *dextrin*, *mannan*, the mother substance of mannose, *glycogen*, and *cellulose* with the general formula $(C_6H_{10}O_5)_n$. The *pectins* derived from the middle lamellæ of many fruits are closely related substances.

Glucosides.—These compounds of glucose, or less often galactose, fructose, rhamnose, or pentose, with other substances occur widely distributed in nature. They are usually water-soluble, bitter substances decomposed by special enzymes into their constituents. Armstrong [1] classifies them according to their non-carbohydrate hydrolytic products under phenols, alcohols, aldehydes, acids, oxycoumarin derivatives, oxyanthraquinone derivatives, oxyflavone derivatives, mustard oils, and various other groups.

Some contain nitrogen, others both nitrogen and sulphur, but the greater number only carbon, hydrogen, and oxygen. Among those occurring in foods are:

GLUCOSIDES

Hesperidin in orange peel, yielding rhamnose, glucose, and hesperetin.
Naringin in grapefruit, yielding rhamnose, glucose, and narigenin.
Amygdalin of bitter almonds and related seeds and *vicianin* of seeds of vetches, both yielding glucose and *d*-mandelonitrile or benzaldehyde and hydrocyanic acid, according to the enzyme.
Apiin in celery and parsley leaves, yielding apiose and apigenin.
Sinalbin of white mustard, yielding glucose, sinapin acid sulphate and acrinyl (sinalbin) isothiocyanate.
Sinagrin of black mustard, yielding glucose, allyl isothiocyanate, and potassium hydro-sulphate.
Saponins of various seeds, yielding glucose, galactose, and sapogenins.

Organic Acids, although widely removed from the carbohydrates, are included in the nitrogen-free extract. They are not present in appreciable amounts in most seeds, whether starchy or oily, but are important constituents of practically all fruits and occur also in other parts such as the petioles of garden rhubarb and the leaves of sorrel. The acid may occur partly free and partly combined. In products of neutral reaction,

[1] The Simple Carbohydrates and Glucosides, New York, 1912.

the presence of oxalate crystals is unquestionable proof of the acid in combined form. Recent work has added greatly to our knowledge of the acids of fruits, but quantitative determinations of the different acids when several are present together are often meager or unsatisfactory.

In Volume II, both the common acids of the aliphatic series that contribute the sour taste, notably *malic*, *citric*, and *tartaric*, and also those of the aromatic series present in small amount, such as *salicylic* and *benzoic*, are given due attention.

Tannins (Tannic Acid).—Tannins occur widely distributed in fruits, spices, tea, coffee, and cocoa. They form a non-nitrogenous group characterized by solubility in water, astringent taste, and the formation of insoluble substances with gelatin, a principle long utilized in tanning. The common reagent for the detection of tannins is ferric chloride solution, with which they give a blue or green color. This color reaction forms a basis for classification. The group is little understood.

Gallotanic Acid, the best known of the group, has the empirical formula $C_{14}H_{10}O_9$. Its exact constitution has not been settled but it appears to consist of two rings with two or three hydrogens of each replaced by hydroxyls and with two additional carbons, of which one at least is in the linkage. On acid hydrolysis it yields *gallic acid*, $C_6H_2(OH)_3COOH + 2H_2O$.

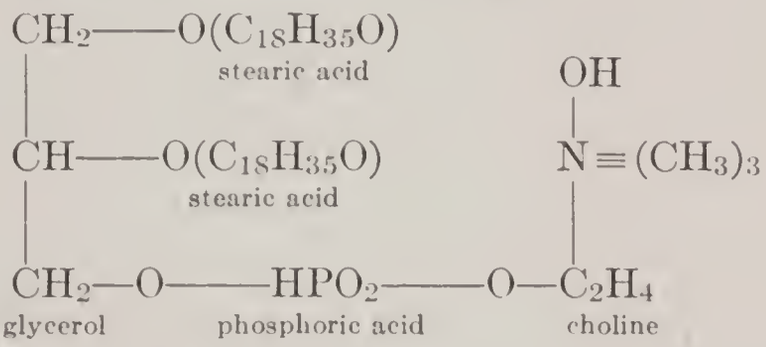
Certain tannins with dilute acid form nearly insoluble brown or dark red *phlobaphenes*, believed to be anhydrides. This term is loosely applied, for want of better names, to insoluble brown cell contents lacking other distinctive characters.

Fiber.—The errors of crude fiber determinations have been a subject for jest among chemists. These are particularly marked when the fiber content is high, as in coarse cattle food, owing especially to the presence of infiltrated substances such as the lignin of woody fibers, stone cells, and other sclerenchymatous tissues, the suberin of cork, and the cutin of cuticles. If one overlooks the fact that an error in fiber causes a like error in nitrogen-free extract, the results are in most instances even more useful than if they represented accurately the amount of the single substance cellulose. Fiber means to the consumer, man and beast, roughage—organic matter that defies solution on boiling with dilute caustic alkali or dilute acid, and hence is not hydrolyzable in the alimentary tract. Formerly, it was customary to determine nitrogen in the fiber and make a suitable deduction, but this small correction is not now commonly made.

Phosphorus-organic Compounds.—In addition to phosphoric acid believed to be in mineral combination, three mixed groups, consisting of phosphoric acid in combination with organic substances belonging under

one or two of the groups of crude constitutents, have received special attention.

Lecithins.—Members of this group consist of glycerol with two bonds in combination with fatty acids as in ordinary fats and the third joined to phosphoric acid which in turn is joined to the nitrogenous base choline. Accordingly, lecithins, dismembered, contribute to the protein, fat, and ash groups. The best-known lecithin with stearic acid as its fatty constituent has the formula $C_{44}H_{90}NPO_9$. The constitutional formula with the names of the radicles follows:



The molecular weight of lecithin is 808; the factor for its calculation from the phosphorus is 26.03, and from the P_2O_5 is 11.38.

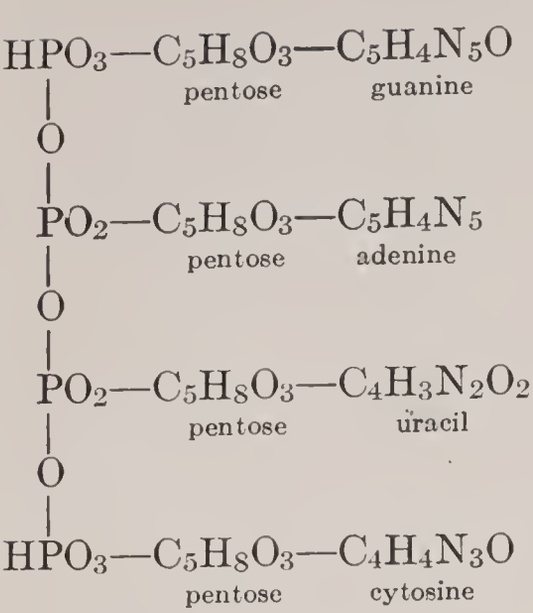
Phytin or Phytic Acid.—This substance, the most abundant phosphorus compound of most seeds, consists of phosphoric acid combined with inosite, which, although having the formula $C_6H_{12}O_6$ and included in the nitrogen-free extract, is not a carbohydrate. Its exact constitution is a matter of controversy. Anderson holds that it is inosite hexaphosphoric acid, $C_6H_6(O \cdot H_2PO_3)_6$, whereas Rather believes that it is inosite pentaphosphoric acid, $C_6H_5(OH)(O \cdot H_2PO_3)_5$.

Nucleic Acids (*Nucleins*).—Plant or yeast nucleic acid, which appears to be identical with the tritico-nucleic acid of wheat, and animal or thymus nucleic acid of the thymus gland are two distinct members of this group whose constitution is now apparently well established. Both contain phosphoric acid in combination with a carbohydrate, two purines, and two pyrimidines. The carbohydrate of plant nucleic acid is pentose, of animal nucleic acid, hexose. The purines guanine and adenine form part of both the plant and the animal acid, as is true also of the pyrimidine cytosine. The other pyrimidine of the plant acid is uracil and of the animal acid is thymine. The formulas assigned to the two substances respectively by Levene and Jacobs [1] and Kossel,[2] and the names of the groups in combination follow: [3]

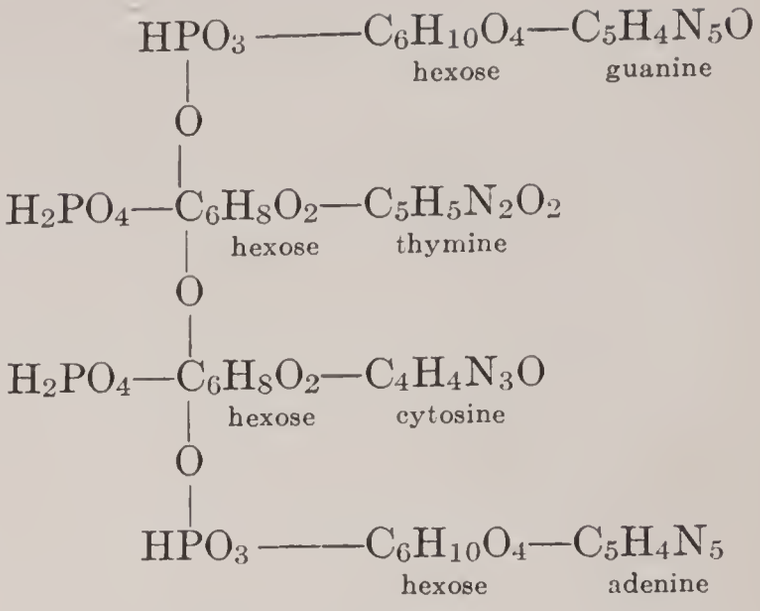
[1] J. Biol. Chem. 1912, **12**, 411.

[2] Arch. Anat. Physiol. 1893, 157.

[3] See, also, W. Jones: Nucleic Acids, New York, 1914; Levene and Bass: Nucleic Acids, New York, 1931.



Plant nucleic acid



Animal nucleic acid

Enzymes.—The presence of enzymes, the catalysts of living cells, is responsible for many changes taking place during growth, ripening, and storage of vegetable foods. Little progress has been made in isolating enzymes in a state of purity or in determining their chemical constitution, although some at least have been shown to be related to the proteins, but much has been learned with regard to their action on cell contents. The leading hydrolytic enzymes, classed according to the substance on which they act, follow:

(1) *Protein or Related Substrate.—Proteases* hydrolyzing directly proteins; *peptidases* that decompose polypeptides; various enzymes, such as *arginase,* that act on amino acids derived from proteins.

(2) *Fat Substrate.—Lipases* or *esterases* that split the glycerides of fats into glycerin and acid.

(3) *Carbohydrate Substrate.—Diastase* or *amylase* utilized since early times in malting and the most studied of vegetable enzymes; *maltase, dextrinase,* and *lactase,* acting respectively on maltose, dextrin, and lactose; *invertase* that splits sucrose into glucose and fructose.

(4) *Glucoside Substrate.—Amygdalase* and *prunase,* the enzymes of emulsin that act successively, splitting amygdalin of bitter almonds with eventual formation of hydrocyanic acid and benzaldehyde; *myrosin* that splits the sinigrin of black mustard into allyl isothiocyanate and potassium-hydrogen-sulphate and the sinalbin of white mustard into sinapin hydrogen sulphate and sinalbin isothiocyanate.

In addition to hydrolytic enzymes there are the fermentation enzymes, such as *zymase* of yeast, also the *oxidases, reductases, catalases,* and special enzymes, each attacking a certain substance and producing definite chemical change. New enzymes are being discovered from time to time, and the subject seems destined to become increasingly com-

plicated until the discovery of fundamental principles brings about simplification.

Activators, or substances essential to the action of the enzymes, and antienzymes, or inhibitive substances, occurring with the enzymes are receiving their share of study.

Animal enzymes, analogous to certain vegetable types, which take part in the digestion of food, are beyond the scope of this work. Those present in meat, fish, eggs, and milk are taken up under these heads.

Ash.—Burned to whiteness at a temperature below redness the ash is assumed to contain all the mineral constituents of the plant and none of the carbon, hydrogen, oxygen, or nitrogen except such oxygen as is required to form inorganic salts and in case of an excess of bases such carbon and oxygen as are required to combine with the excess to form carbonate. During burning, part of the sulphur, chlorine and certain minor constituents may escape. The ash should be free from charcoal, but sand is considered a part of the total ash, at least it must be included in the sum to be deducted from 100 in calculating the nitrogen-free extract. The distinction between sand from spattered mud or dust and silica from chaff and other parts containing silica as a normal constituent is not always sharply marked. It has been considered that when the ash contains carbon dioxide this should be deducted from the total ash, otherwise the nitrogen-free extract will be too low, but this assumes that the carbon was derived from organic combination—which is not certain to be the case. The sulphur that exists as sulphate in the ash was doubtless present in the plant largely as a constituent of protein molecules, hence theoretically this also should be determined and deducted. Efforts to refine the scheme of ash analysis so as to avoid all overlapping seem futile in view of our limited knowledge of the forms in which the mineral constituents exist in the plant or animal tissues and the considerable errors beyond our control.

In many analyses of fruits the alkalinity of the ash is given. This value runs parallel with the carbon dioxide content and is useful alike to the nutritionist and the inspection chemist.

Mineral Constituents.—The ash analyses by agricultural chemists are designed chiefly as a measure of soil exhaustion. They serve also a most important purpose in calculating the amount of the essential mineral constituents in the diet. Under each product, in addition to the usual analyses showing the content of potash (K_2O), soda (Na_2O), lime (CaO), magnesia (MgO), iron oxide (Fe_2O_3), phosphoric acid (P_2O_5), sulphuric acid (SO_3), silica (SiO_2), chlorine (Cl), and in some cases carbon dioxide (CO_2), there is given a compilation of results on the *minor constituents* iron (Fe), alumina (Al), manganese (Mn), copper

(Cu), zinc (Zn), arsenic (As), and iodine (I) as determined during recent years.

In earlier analyses and many recent ones the results (excepting chlorine) are in terms of oxides; in some recent analyses, however, they are in terms of the elements or less often ions. The percentages are partly calculated to the original substance, whether fresh, air-dry, or water-free, and partly to the ash itself. Some analyses on the latter basis give the sand and carbon dioxide, whereas others are calculated free of both, the constituents other than these adding to 100.

The writers have recalculated a considerable number of analyses to facilitate comparison, but for lack of data this has not been done in all cases. When neither the content of carbon dioxide nor alkalinity of ash is given, the reader must make a laborious calculation in order to determine whether the ash is neutral or alkaline. In general, it may be stated that the ash of seeds is neutral, and that of fruits and vegetables other than seeds is alkaline.

Range in Composition.—Compilations of analyses show considerable variation in the percentage of each constituent in the same product. Excepting high percentages, such as starch in cereals and water in fruits and green vegetables, in many cases the ratio of the minimum result to the maximum is as wide as one is to two and the variation of the extremes from the average as much as one-third. It is accordingly obvious that the average composition, as given in a compilation, is merely suggestive and cannot be accepted as a close approximation to the truth. An actual analysis is essential in the accurate calculation of dietaries, in commercial valuation, in official inspection, and in various investigations.

Calculation of Water-free Analyses.—One of the chief sources of the wide range in the percentages of the individual nutrients is the difference in water content. Even carefully cured grain shows great variation dependent on original water content, climate, method of storing, and other factors. Strict comparison, where the question of yield or total weight of a shipment is not concerned, should be made either on the dry (water-free) basis or the basis of an assumed uniform water content. Averages of analyses (not minimum and maximum percentages) may be calculated readily to the dry basis by multiplying each constituent by 100 and dividing by the per cent of dry matter, whether obtained by direct determination or by subtracting the per cent of water from 100.

Calculation of Calories.—Figures for calories of the individual foods are not given in this work. These may be found in Atwater and

Bryant's "Chemical Composition of American Food Materials"[1] or may be calculated from the average analyses (not minimum and maximum figures) by the following formulas based on Rubner's values:

$$\text{Calories per pound} = 18.6(P + C) + 42.2F$$

$$\text{Calories per 100 grams} = 4.1(P + C) + 9.3F$$

in which P = per cent of protein, C per cent of total carbohydrates (nitrogen-free extract and fiber), and F per cent of fat.

These formulas assume that all the carbohydrate matter is digestible, which is not true of the fiber.

[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. 28 rev.

PART I

CEREALS

PART I

CEREALS[1]

In this part are grouped not only the true cereals—the edible "seeds" (fruits) of the grass family—but also starch seeds, such as buckwheat, chestnut, and various weed seeds, of other families, which are similar in composition to the true cereals and are classed as cereals in the broad sense. This use of the term cereals, although no longer sanctioned by lexicographers, is still retained in commerce, at least as regards buckwheats. Sometimes even dry legumes are included.

The term starch seeds is used to designate those seeds and dry fruits that contain starch as the chief constituent, and not those which may contain an amount of starch which, although appreciable, is much less than that of the oil. Peanut and cashew kernels, for example, contain about 10 per cent of starch, but the presence of about five times that amount of oil places them definitely in the oil seed category. Overlooking these and a few trivial exceptions, the oil seeds described in Part II of this volume are practically starch-free; the starch seeds, on the other hand, in no case are oil-free, the oil content ranging from 1 or 2 to about 10 per cent, and the starch content ranges with few exceptions from 70 to over 90 per cent calculated to the dry basis. However, some of the starchy nuts, notably the chestnut and the acorn, have a portion of the starch replaced by sugars and other soluble carbohydrates so that the actual amount of starch is only about 50 per cent. This lower starch content does not disqualify them from being ranked as starch seeds, especially as their oil content is low.

Black and white pepper, though comparable with the cereals in starch content, obviously belong in a separate category by reason of their pungent qualities that unfit them for satisfying the demands of hunger.

As a fitting introduction, the initial chapter is on starch, its physiological significance, structure, chemical composition, and commercial varieties. It should be noted that the source of some of the varieties described is not seeds but subterranean organs, but this inconsistency seems negligible compared with the greater need of a clear understanding of the significance of starch in relation to the group of seeds that furnishes man and beast with their chief source of nutriment.

[1] With an introductory chapter on starch.

STARCH

THE importance of starch was early recognized and made the subject of numerous investigations—botanical, physical, and chemical. Nägeli in his classical work [1] studied the starch in no less than 2500 species of plants, both as to its microscopic characters and its reactions.

Relation of Family to Starch Content.—Starch is present in seeds of flowering plants low in the scheme of classification, such as ginkgo and pine, the latter classed with oil seeds, and is abundant in the seeds of the true cereals among monocotyledons and of buckwheats and various weeds among dicotyledons. In seeds of the orchids and composites, the highest families of the two classes, as well as of many lower families, starch is entirely lacking, the reserve material being largely in the form of oil and protein or else in cell-wall material.

Function of Starch.—In all green plants, starch is the first demonstrable product of assimilation (*assimilation starch*), and in many plants it is the last product formed before they enter on the resting season or perish with the frost. *Reserve starch*, designed for the plant's own use, is deposited either in subterranean parts—rhizomes (Bermuda arrowroot, curcuma), tubers (potato), corms (taro), fleshy roots (cassava), root tubers (sweet portato, yam)—or in the trunk of the plant (sago). The starch of the banana, though formed in much the same manner as true reserve starch, serves apparently no directly useful purpose either to parent or progeny, the seeds of the common species being abortive. Whether or not the plant itself survives until the next resting season, it usually provides for the nourishment of its progeny during the sprouting stage and before green leaves form by depositing in the seed reserve food of which reserve starch is the outstanding example. This deposit in the seed remains practically unchanged until the sprouting season, when it is transformed by enzyme action into soluble carbohydrate as needed by the plantlet. The location of this reserve starch may be in the embryo itself, chiefly in the fleshy cotyledons (chestnut, horn chestnut), in the endosperm (cereals, buckwheats), or in the perisperm or enlarged body of the ovule (pigweed, lamb's quarters).

Transitory Starch, an intermediate product of growing points, barks, and immature fruits and seeds, need not here be considered.

[1] Die Stärkekörner, Zurich, 1858.

Formation of Starch.—Schimper [1] first demonstrated that the grains of reserve starch are not deposited directly from the protoplasm of the cell but are formed from leucoplasts, microscopic bodies related to chloroplasts or chlorophyl grains which are the agents in the formation of assimilation starch in the green leaf, and chromoplasts, which are the color bodies of flowers, fruits, and roots. Leucoplasts, like chromoplasts, are active in the dark; chloroplasts, however, are dependent on light.

Structure of Starch Grains. *Shape.*—Arthur Meyer [2] has shown that when a starch grain is developed within a leucoplast it will be rounded on the surface and have a central hilum and more or less conspicuous circular concentric rings. If an aggregate is thus formed, the individuals will of necessity have flattened surfaces where in contact. If, however, the formation begins on the side of a leucoplast, the growth will be chiefly on that side, and as a consequence the grain will be elongated with an excentric hilum and excentric rings. In general, it may be stated that when the grains or aggregates of different sizes are loose in the cell and not closely crowded they are rounded in outline, whereas when crowded together, either in aggregates (rice, oats) or in the cell masses (maize), they are polygonal or at least with one or more truncations. Individuals of an aggregate of two grains have one truncation and may be hemispherical (kettledrum-shaped), conoidal (sugarloaf-shaped), or bulb-shaped; those of aggregates of three grains have two truncations, and so on.

The following classification, according to shape of the individual, covers the commonest forms: (1) globular (peanut, floury part of maize); (2) lenticular (large grains of wheat, rye, barley); (3) ellipsoidal (legumes); (4) pear-shaped (potato, canna, banana, Bermuda arrowroot, yam, horse chestnut, etc.); (5) truncated, including hemispherical or kettledrum-shaped, conoidal, or sugarloaf-shaped, or bulb-shaped (cassava, batata, sago); (6) polygonal (maize, sorghum, grains from interior of aggregates of rice, oats, etc.); and (7) bone-shaped (latex of species of *Euphorbia*). Hemispherical and conoidal grains, when resting on their flat surface, are with difficulty distinguished from those which are globular, hence the latter term is well avoided when truncated forms occur in considerable numbers.

Size.—The range in size is remarkable. In cockle the grains are about 1 μ in diameter, whereas in *Canna lanuginosa* they reach 170 μ. As a rule, the smallest grains occur in seeds; the largest, in subterranean parts (canna, potato, Bermuda arrowroot, coontie). Some subterranean starches, however, have minute grains less than 10 μ (taro), and

[1] Bot. Ztg. 1880, **38**, 881.

[2] Ibid. 1880.

some seeds have medium-large grains (rye, wheat, legumes, horn chestnut). In the same cell with large grains occur those of small or even minute size, hence it is customary to describe separately the large and the small grains of different species.

Hilum.—The point or organic center about which the starch grain is formed in successive layers is known as the hilum. Usually it is minute or scarcely recognizable, but in some starches, such as maize, it appears to be of considerable size or is clearly located by radiating fissures. The hilum of leguminous seeds appears to be elongated, but, as will be brought out in the description of the seeds of that family, what appears to be an individual grain is really an aggregate of two grains.

Rings concentric with the hilum are more or less distinct in the larger grains. When visible, they bring out clearly the location of the hilum and show the alternately different character of the layers forming the grain. The difference in appearance of the rings is believed by some to be due to difference in water content, by others to difference in composition.

Polarization Phenomena (Fig. 37).—With crossed Nicol prisms starch grains show, more or less distinctly, dark bands crossing at the hilum which contrast with the otherwise white grain. These not only locate clearly the position of the hilum but by their degree of distinctness furnish diagnostic evidence. Some starches, such as wheat, rye, and barley, show little contrast between the crosses and the illuminated portion of the grain; others, such as potato and various subterranean starches and maize, give a cross of inky blackness, the remainder of the grain being of dazzling whiteness. Leguminous starches (Fig. 37, IV) with crossed Nicols show two dark V's, one at each end of what appears to be a single grain, joined by a line through the center, hitherto regarded as marking the position of an elongated hilum. In reality each V is the polarization cross of a separate grain with a very excentric hilum.

A selenite plate used in conjunction with the polarizing apparatus brings out a beautiful play of colors with certain starches, such as canna and potato, that show distinct polarization crosses. All these optical phenomena go to show the crystalline nature of starch grains, which are regarded as doubly refractive sphærocrystals.

Chemical Nature of Starch.—The simple formula $C_6H_{10}O_5$ adopted by Liebig a century since still holds good for most practical purposes. There is evidence, however, that the true formula is some multiple of the simple one. The English chemists Brown and Millar [1] give as their idea of the molecule the empirical formula $(C_6H_{10}O_5)_{200}$, made up of four maltan groups, $(C_{12}H_{20}O_{10})_{20}$, and one dextran group, $(C_6H_{10}O_5)_{40}$, each of complex constitution.

[1] J. Chem. Soc. Trans. 1899, **75**, 333.

As shown by Nägeli, granulose, now known as *β-amylose*, forming by far the greater part of the starch grains, dissolves in saliva or malt extract leaving a delicate skeleton of amylocellulose (starch cellulose) now known as *α-amylose*. Arthur Meyer [1] states that these two compounds, both staining blue with iodine in potassium iodide, are isomers as is also the amylodextrin of Tschirch, occurring in maize and elsewhere, which stains red with the iodine reagent. Certain kinds of starch which stain reddish blue are assumed to contain an admixture of *amylodextrin*.

Since the World War much work on the chemistry and composition of starch has been conducted in European laboratories. Although some disintegration products of starch have been identified and addition products of these have been prepared by acetylation, halogenation, and in other ways, little advance has been made in determining the constitution of starch itself. Overlooking traces of amylocellulose, starch has come to be regarded as a mixture of amylose and amylopectin, the latter containing H_3PO_4 in its molecule. The small amount of ash in starch formerly was classed as an impurity. Possibly the method of ashing caused a loss of part of the phosphorus.

Ling and Nanji [2] state that potato and arrowroot starch consist practically entirely of amylose and *amylopectin*, which they prepare as follows: starch in fibrous form is precipitated from starch paste by allowing it to stand 10 to 12 hours at 0° C., and amylopectin is separated from the more soluble amylose of the starch by keeping at a temperature just short of gelatinization. On drying, the amylopectin forms transparent scales. Amylose is separated from the solution by evaporation and precipitation with alcohol. Amylopectin gives a blue-black precipitate with iodine in potassium iodide; amylose, a bright blue solusion. The former is considered to be a phosphoric acid ester of α, β-hexaamylose, the two hydroxyl groups adjacent to the β-linkings being esterified.

Steingroever [3] obtained amylopectin triacetate by acetylating amylopectin, prepared by the Ling and Nanji method, which on decomposition yielded H_3PO_4, thus adding to previous evidence that phosphorus is a constituent of the molecule.

Ling and Nanji [4] calculate the percentage of amylose of different starches from the maltose into which it passes on digestion with barley diastase, with the following results: arrowroot 65.8, potato 67.2, wheat

[1] Unters. die Stärkekörner, Jena, 1895.
[2] J. Chem. Soc. 1923, **123**, 2666.
[3] Ber. 1929, **62B**, 1352, published in Pringsheim's series.
[4] J. Chem. Soc. 1925, **127**, 629, 652.

66.3, barley 68.2, and rice 66.2. In the case of arrowroot and potato starch, the remainder of the starch consists of amylopectin. If amylodextrin is present it changes with diastase to α, β-hexaamylose. Certain starches contain amylohemicellulose, believed to be a lime-magnesia or iron salt of a silicic ester derived from α-hexaamylose, as follows: rice 19.15, wheat 10, and barley 7.68 per cent.

Meyer, Hopff, and Mark [1] are convinced that maltose exists in some form in the starch molecule, since it is a product of several distinct reactions both enzymic and purely chemical, but are uncertain whether β-unions alternate with α. A series of complicated reactions takes place during hydrolysis, only the last of which—the hydrolysis of maltose—is understood. They state that amylopectin is crystalline but that amylose is not.

Pringsheim and Wolfsohn [2] depolymerized amylose into a disaccharide and, amylopectin into a trisaccharide, both changes being in harmony with the idea that the basic unit of amylose must contain at least two and that of amylopectin at least three dextrose residues.

Pringsheim [3] later states that the commonly accepted view that maltose residues constitute the starch molecule is confirmed by the discovery that, after maltose formation with amylase stops at 80 per cent, it may be continued to nearly 100 per cent by utilizing the complement present in yeast.

Other valuable investigations, chiefly on the derivatives of starch, have been carried out in the laboratories of Pringsheim, Karrer and Pictet, and various formulas for the constituents of the starch grain have been suggested.

Zwikker in 1921 [4] stated that our knowledge of the constitution of starch is limited to its empirical formula and the fact that it consists of a mixture, one constituent of which contains H_3PO_4. He later [5] submits three-dimension models formed by rods representing hexose molecules with knob-ends marking the position of the CO group. Starch is shown as a tetrahedron, cellulose as a triangular prism.

Even as late as 1926 Peiser [6] returned to the idea that starch is an individual substance of much simpler constitution than now commonly believed with about 1 per cent of impurity, consisting of calcium phosphate, silica, and nitrogenous matter, which he considers forms a coating on the surface of the grains. By acetylating dried starch paste in the

[1] Ber. 1929, **62B**, 1103.
[2] Ibid. 1924, **57B**, 887.
[3] Ibid. p. 1581.
[4] Rec. trav. chim. **40**, 605.
[5] Ibid. 1922, **41**, 49.
[6] Z. physiol. Chem. 1926, **161**, 210.

cold, a product containing eight monosaccharides and twenty-six acetyl groups was prepared.

Still more recently, Pringsheim and Will [1] are forced to the admission that no successful degradation of starch to the building stones has yet been accomplished.

Properties of Starch.—On boiling with water, starch swells and passes into colloidal solution. It dissolves in potassium or sodium hydroxide solution, hence the use of this reagent in clearing mounts for observation of the cellular residue.

On hydrolysis with diastase or saliva at 40° C., starch passes into maltose ($C_{12}H_{22}O$), and by boiling with dilute acid it changes through a series of dextrins into maltose and finally into glucose. Heated dry at 150 to 160° C., starch is converted into dextrin.

The *iodine reaction* has been used since early in the nineteenth century. The reagent commonly is prepared by dissolving 0.05 gram of iodine and 0.2 gram of potassium iodide in 15 cc. of water, but the exact strength is unimportant. The blue color appears with a minute amount of the reagent. Tincture of iodine also gives a blue color if water is added to the dry starch or the starch is made into a paste. Alkali discharges the color but neutralization with acid causes it to reappear.

It has been generally held that the blue color of starch treated with iodine in potassium iodide is an adsorptive phenomenon, but Bergmann and Bergmann and Ludewig [2] present evidence that points to the formation of a compound containing both iodine and potassium iodide. This view has been confirmed by Pringsheim and Steingroever.[3]

Gelatinization of Starch.—Lippmann and other chemists have devoted considerable attention to the temperature of gelatinization of different starches. In Lippmann's table are given the temperatures at which swelling is first noted, at which gelatinization begins, and at which gelatinization is complete. For example, the temperatures for rye starch are, respectively, 45°, 50°, and 55°; for wheat starch, 50°, 65°, and 67.5°; for maize starch, 50°, 55°, and 62.5°; and for potato starch, 46.2°, 58.7°, and 62.5° C.

Nyman [4] does not find so much difference in the gelatinization temperature but notes a decided difference in the time required for gelatinization at a given temperature, thus at 53° C. rye starch required only 6 minutes for gelatinization whereas wheat required 24.

[1] Ber. 1928, **61B**, 2011.
[2] Ibid. 1924, **57B**, 753, 961.
[3] Ibid. p. 1579.
[4] Z. Unters. Nahr.-Genussm. 1912, **24**, 673.

Alsberg and Rask,[1] working with wheat and maize starch, found that the viscosity increases gradually through 25 to 30°, and that there is probably no definite temperature of gelatinization.

Lenz [2] depends on the time required for the swelling of the grains in a solution of sodium salicylate (1 : 11) at ordinary temperatures. A drop of the solution is placed on a cover glass, a small amount of a pasty mixture of starch and water is added, the cover glass is inverted on a vaselined ring attached to a slide and the changes in the starch in this wet chamber are observed under the microscope. In 10 to 15 minutes the grains of rye starch begin to swell, as shown by the disappearance of polarization crosses, and after 1 hour are mostly swollen, whereas the grains of wheat starch in 1 hour show little change and in 24 hours for the most part still hold their shape and show polarization crosses.

Röntgen Spectrum of Starches.—All native starches have different and characteristic spectra, according to Katz and co-workers,[3] which change during baking or paste formation. The first stage of paste formation with swelling of the grains is brought about by heating wheat starch with a large amount of water to 60 to 62.5° C. or with a small amount of water to 100° C. as in baking. The second stage, with formation of sacs filled with the starch solution, results when a large amount of water is used and the temperature reaches 100° C. The spectra in the first stage are markedly different but in the second stage show retrogradation, much alike in all varieties, approaching those of the unheated starch of the potato and canna group. Gelatinization phenomena by sodium hydroxide of different strengths are analogous to the stages in the mercerization of cellulose. Changes in the Röntgen spectra are also produced by drying.

COMMERCIAL STARCHES

Of the numerous starchy foods only a comparatively few are suited for the manufacture of starch. Several factors are taken into consideration, such as the raw material available in each region, the starch content and yield, and the quality of the starch, especially as measured by its taste and physical properties. On the Continent wheat and potato are the most important starches; in England, rice starch takes the lead; in the United States, corn starch is made to the practical exclusion of all others. Cassava, sago, curcuma, yam, canna, maranta, tacca, and some other varieties are made in the tropics or subtropics.

Although description of all the varieties that have been mentioned in the literature was found impracticable because of the difficulty of

[1] Cereal Chem. 1924, **1**, 107.

[2] Z. öffent. Chem. 1909, **20**, 224.

[3] Z. physik. Chem. 1930, A **150**, 37, et seq.

securing authentic material, the writers, through the generous assistance of friends abroad and in the Bureau of Plant Industry of the U. S. Department of Agriculture, have been able to collect data on thirty-six varieties, some of which appear to have escaped the notice of authors of works on microscopy. Among the unusual varieties are the starches from the horn chestnut and the water chestnut of China and the araucaria of Brazil, all with unique characteristics.

The variety of forms of the starch grains present in some of the starches is so great as to baffle description, hence only a few which appear to be most common are mentioned. In this particular, the cuts will be found more illuminative than the text. Only the maximum size of the grains is given, and this with some misgivings, as samples of unquestioned authenticity show considerable variation. The *excentricity* is expressed as a ratio, the two members of which represent the relative distances of the hilum from the two ends.

POTATO STARCH.—The tubers of the common or Irish potato, *Solanum tuberosum* L. (*Solanaceæ*), yield a starch formerly important commercially in the United States but now largely displaced by maize (corn) starch. It is still made in Europe and is used to some extent for food, in the manufacture of glucose, and in the arts. The process of manufacture is quite simple, involving merely grating of the tubers, washing on sieves, settling, and drying the moist starch. The individual grains are visible to the naked eye.

Microscopic Structure (Plate I, Fig. 1).—Large grains ellipsoidal, ovoid, or irregularly lobed, narrow end uniformly rounded, opposite end rounded, truncated, blunt-pointed, or notched, length up to 100 μ; medium large grains sometimes in aggregates; hilum distinct, usually in narrow end, occasionally double, excentricity 1 : 3 to 1 : 6; rings and polarization cross (Fig. 37) very distinct, brilliant play of colors with selenite plate. Small grains rounded, sometimes in aggregates of two or three individuals.

Description is of starch from fresh tuber and commercial starch.

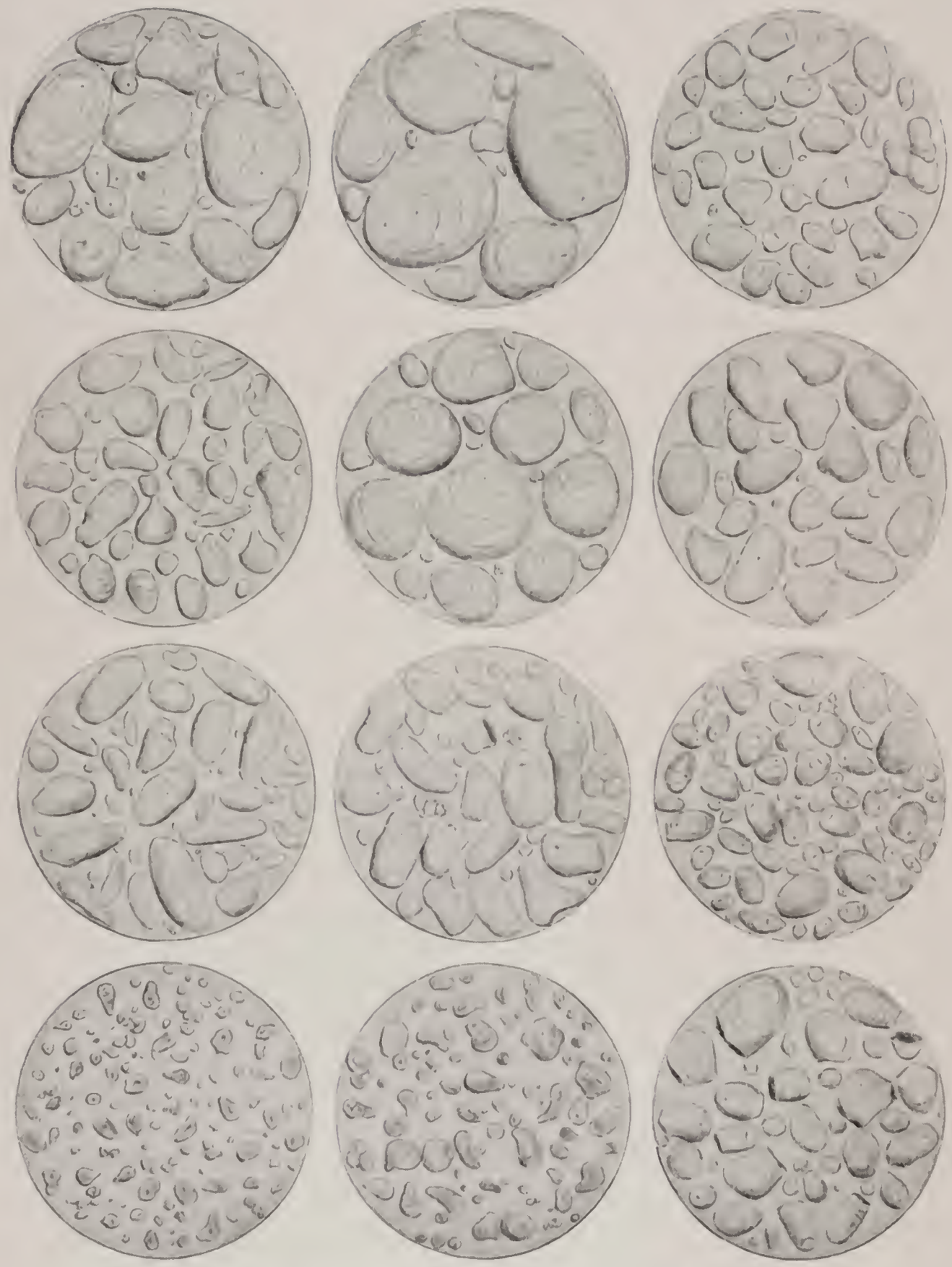
Chemical Composition.—König [1] compiled 14 analyses showing the following range:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min	13.34	0.15	0.02*	76.07†	0.02*	0.19
Max	22.42	1.88	0.07*	82.92†	0.14*	1.68

* 5 Samples. † 7 Samples.

[1] Chem. mensch. Nahr.-Genussm. Berlin, 1903, **1**, 655.

PLATE I



Commercial Starches. ×160. (A.L.W.)

FIG. 1 Potato
4 Curcuma
7 Banana
10 Chestnut

FIG. 2 Canna
5 Frittilaria
8 Lotus Rhizome
11 Horse-Chestnut

FIG. 3 Maranta
6 Yam
9 Clinogyne
12 Sago

Obviously the samples with high protein and ash content were not properly purified.

Winton [1] in potato starch, made by him with special care without the use of chemicals, found: water 15.17 and ash 0.62 per cent.

CANNA STARCH also known as Queensland, New South Wales, or East Indian arrowroot or *tout-les-mois*, is made from the rhizomes of *Canna edulis* Edw., *C. coccinea* Rosc., *C. indica* L., *C. Achiras* Gill, and other species of the genus *Canna* (*Marantaceæ*) growing in Australia, the East Indies, Brazil, Venezuela, Réunion, and other warm regions. The individual starch grains are the largest found in natural products used as food and are clearly evident without a lens.

Microscopic Structure (Plate I, Fig. 2).—Large grains broadly oval or ovoid, hilum end usually with blunt obtuse angle between two shoulders, opposite end broader, well rounded, length up to 145 μ; hilum distinct, sometimes double, excentricity up to 1 : 7; rings distinct; polarization cross very distinct, play of colors exceptionally brilliant. Small grains similar to large, seldom in aggregates.

Description is of starch exhibited at Centennial Exposition, Philadelphia, 1876.

Chemical Composition.—The undried rhizome grown in Hawaii contained, according to Ripperton and Goff [2]: water 77.3, protein 0.49, fat 0.08, nitrogen-free extract 19.2, fiber 2.4, ash 0.6, potash (K_2O) 0.19, lime (CaO) 0.07, and phosphoric acid (P_2O_5) 0.15 per cent. No analysis of the starch is at hand.

MARANTA STARCH, also known as Bermuda, Jamaica, St. Vincent, Natal, and West India arrowroot, prepared from *Maranta arundinacea* L. (*Marantaceæ*), was formerly the only starch known as arrowroot, but now several starches pass under that name. The process of manufacture is like that described under potato starch. This arrowroot is prized for making invalid gruels but is now largely displaced by a superior grade of maize starch.

Microscopic Structure (Plate I, Fig. 3).—Large grains exceedingly variable in shape, ovoid, spindle-shaped, rounded-triangular, etc., often with protuberance on side, length up to 60 μ; hilum variously located, often with two fissures suggesting soaring bird, excentricity of large grains about 1 : 4; rings distinct; polarization cross and play of colors with selenite plate striking; aggregates of medium-sized grains sometimes present. Small grains characterless.

Description is of starch exhibited at Centennial Exposition, Philadelphia, 1876.

[1] J. Anal. Chem. 1888, **2**, 149.

[2] Hawaii Agr. Exp. Sta. 1928, Bul. **57**.

CURCUMA STARCH.—Other names are East India or Travencore starch, Tik, Tikor, and Tikur. The starch is obtained from the rhizomes of *Curcuma angustifolia* Roxb., *C. Leucorrhiza* Roxb., *C. rubescens* Roxb., and other species of the genus, which together with turmeric (*C. longa*) and ginger belong to the order *Zingiberaceæ*.

Microscopic Structure (Plate I, Fig. 4).—Large grains often greatly elongated, pear-shaped, sack-shaped, or club-shaped, much narrowed at one end, length up to 75 μ; hilum often close to the narrow end, excentricity seldom less than 1 : 6 and reaches 1 : 15 or over; rings distinct, also polarization cross (Fig. 37) and play of colors with selenite plate.

Description based on material furnished by Lt.-Col. Sir David Prain, I.M.S., M.B., LL.D., etc., Director of Royal Botanic Gardens, Kew, England.

FRITTILLARIA STARCH.—The bulb of the crown imperial, *Frittillaria imperialis* L. (*Liliaceæ*), is rich in starch which is said to be extracted in certain parts of France for local use.

Microscopic Structure (Plate I, Fig. 5).—Large grains nearly isodiametric, narrow end blunt-pointed, broad end well rounded, length up to 90 μ; hilum in blunt point; excentricity 1 : 3 to 1 : 6; rings evident; polarization phenomena as in canna. Small grains often in small aggregates.

Description is of starch extracted from garden bulb.

YAM STARCH.—The rhizome of *Dioscorea alata* L. (*Dioscoraceæ*) is the chief source of this starch. Other species yielding commercial starch are *D. sativa* L., *D. aculeata* L., *D. glabra* Roxb., *D. japonica* Thbg., *D. nummularia* Lam., and *D. tomentosa* Koenig.

Microscopic Structure (Plate I, Fig. 6).—Large grains ellipsoidal or elongated ovoid, one end often narrow and bent, broad end rounded or rounded-truncated, length up to 55μ; hilum in narrow end, excentricity 1 : 3 to 1 : 7; rings evident; polarization phenomena striking.

Grains of *D. trifida* with narrow end broader, indistinctly bent, broad end with rounded truncation, up to 85 μ long.

Description is of starch exhibited at Centennial Exposition, Philadelphia, 1876.

BANANA STARCH is made from the fruit of both the true banana and the plantain, both being species of *Musa* (*Musaceæ*). Since the starch is changed to sugar during ripening, only the green fruit is suited for starch manufacture. Tropical America is the chief region of production.

Microscopic Structure (Plate I, Fig. 7).—Large grains much elongated sausage-, sack-, pear-, or sickle-shaped, length up to 85 μ; hilum usually in narrow end, excentricity 1 : 6 to 1 : 10; rings distinct; polarization

phenomena pronounced. Small grains often in aggregates of two or three.

Description is of starch from green banana.

LOTUS RHIZOME STARCH.—This starch, from *Nelumbo nucifera* Gærtn. (*Nymphæaceæ*), is made in the Orient.

Microscopic Structure (Plate I, Fig. 8).—Large grains much elongated, one end usually rounded, other end rounded-truncated, sometimes with excrescence on side, length up to 100 μ; hilum in rounded end, excentricity about 1 : 5; rings distinct; polarization phenomena marked. Small grains isodiametric, often in aggregates of two or more.

Description is of starch from rhizomes furnished by Dr. Mantaro Kondo, Director of Ōhara Institute, Kuraschiki, Japan, and from Chinese Quarter, New York City.

CLINOGYNE STARCH.—Rhizomes of *Clinogyne dichotoma* Salsb. (*Marantaceæ*), a native of Asia but also grown in Liberia and other parts of Africa, yield a commercial starch.

Microscopic Structure (Plate I, Fig. 9).—Large grains mostly ovoid, sometimes with protuberances on side, length up to 55 μ; hilum usually in broad end, often with clefts, excentricity 1 : 1 to 1 : 6; rings usually distinct; polarization phenomena brilliant. Small grains sometimes in small aggregates.

Description is of starch from the New York Botanical Garden.

CHESTNUT STARCH is made from the European chestnut, *Castanea sativa* Mill. (*Fagaceæ*).

Microscopic Structure (Plate I, Fig. 10).—Large grains commonly pear-shaped, ovoid, or irregular, length up to 24 μ; hilum central or in broad end; excentricity 1 : 1 to 1 : 5; rings not conspicuous; polarization cross distinct but not striking. Small grains isodiametric, often in small aggregates.

Description is of starch from the nut and from chestnut flour imported from Italy.

HORSE-CHESTNUT STARCH.—This starch as commonly prepared from *Æsculus Hippocastanum* L. (*Hippocastanaceæ*) is bitter but doubtless could be purified so as to be suited for food.

Microscopic Structure (Plate I, Fig. 11).—Similar to chestnut starch but with large and more irregular grains. Large grains isodiametric or much elongated, often with a bent tail, length up to 40 μ; hilum in broad end, sometimes obscured by clefts as in legumes; rings evident; polarization cross not conspicuous. Small and medium-sized grains isodiametric, often in aggregates of two or three.

Description is of starch from the Centennial Exposition, Phila-

delphia, 1876, from the collection of Prof. C. W. Ballard, New York College of Pharmacy, and direct from the nut.

SAGO STARCH.—Enormous quantities of starch are separated in India and the East Indies from the pith of palms and cycads, notably *Metroxylon Rumphii* Mart. (*Sagus Rumphii* Willd.) and *M. læve* (*S. læris* Rumph.). Species of secondary importance are *M. Sagus*, *M. Koenigii* Rumph., *Arenga saccharifera* Labill, *Borassus flabelliformis* L., *Caryota urens* L., *Cycas revoluta* L., and others. The process of separation is essentially the same as used for subterranean varieties. Both the starch and pearl sago are made, the latter, analogous to pearl tapioca, consists of coarse granules of the moist starch heated until they agglutinate.

Microscopic Structure (Plate I, Fig. 12).—Large grains irregular in shape with one or more sharply defined truncations on surfaces once in contact with other grains in an aggregate, diameter up to 80 μ; hilum in the rounded end, sometimes with clefts; excentricity 1 : 3 to 1 : 5; rings distinct; polarization cross sharply defined. Small grains similar to large grains in form. The product when made by primitive methods may contain raphides, crystal rosettes, cell detritus, etc. In pearl sago the starch grains are more or less distorted owing to the heating.

Description is of commercial sago.

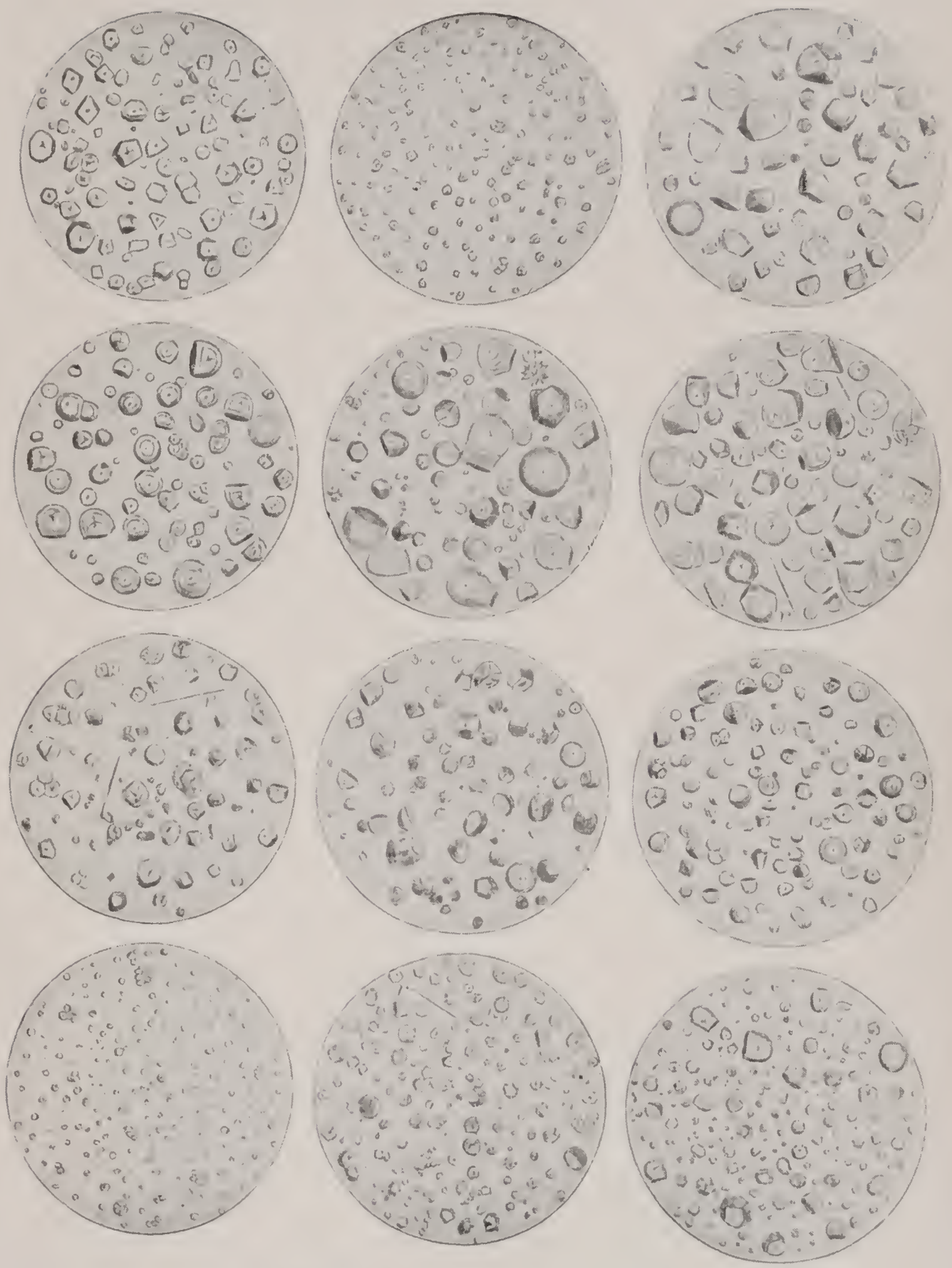
Chemical Composition.—Greshoff, Sack and Van Eck [1] found in 4 samples of sago:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	14.45	0.13	0.10	78.16	0.13	0.16
Max.	16.24	1.12	0.19	84.87	0.41	0.72

MAIZE STARCH.—The separation of "green" or moist starch from the maize kernel, *Zea Mays* L. (*Gramineæ*), is conducted on a large scale in the United States preliminary to purification for technical, laundry, or food use and the manufacture of commercial glucose and other saccharine products. The process is in some respects similar to that of gradual reduction in flour milling, differing in that the grain softened by soaking in warm water containing a little sulphurous acid is ground while moist, and the starch is separated from the germ, bran, and other impurities by washing on sieves and passing through tanks of water where, by reason of its greater specific gravity, it settles out from

[1] König, Chem. mensch. Nahr.-Genussm. 1903, **1**, 1488.

PLATE II



Commercial Starches. ×160. (A.L.W.)

FIG. 13 Maize
16 Cassava
19 Arum
22 Taro

FIG. 14 Rice
17 Sweet Potato
20 Arracacha
23 Yautia

FIG. 15 Kudzu
18 Tacca
21 Bean Tree
24 Yam Bean

the proteins. The green starch is purified and dried, an alkaline solution being used in some cases to facilitate the removal of the protein, care being taken to wash after the treatment until neutral. Corn starch designed for food purposes is specially purified and marketed in the form of a fine powder. Further details of the manufacturing process are given by Sherman.[1]

Microscopic Structure (Plate II, Fig. 13).—Large grains for the most part sharply polygonal (from horny endosperm), much less often round (from floury endosperm), diameter up to 30 μ; hilum central, very distinct, often with radiating clefts; rings seldom evident; polarization cross striking; no marked play of colors with selenite plate. Small grains mostly isolated, not in definite aggregates.

Description is of commercial "corn starch."

Chemical Composition.—Analyses of German, English, and American maize (corn) starch by Saare [2] show as follows.

	Samples	Water	Protein	Fat	Ash	Acidity*	Alkalinity †
		%	%	%	%	cc.	cc.
German:	4						
Min.		14.33	0.36	0.02	0.10	0.0	
Max.		15.70	0.65	0.04	0.13	4.3	
English:	2						
Average		12.81	0.27	0.03	0.35	.....	33.7
American:	2						
Average		14.13	0.27	0.03	0.41	.....	30.3

* Cc. N/10 alkali per 100 grams starch.
† Cc. N/10 acid per 100 grams starch.

RICE STARCH is made in large quantities in England and to some extent on the Continent from Indian paddy (*Oryza sativa* L.). Alkali or other chemical is used in the process to remove the protein matter which cements together the starch grains of the horny endosperm, the starch being finally washed free from all extraneous matter. The chief uses of rice starch are as a cosmetic, in the laundry, and in the arts.

Microscopic Structure (Plate II, Fig. 14).—Grains mostly polygonal; diameter 2 to 10 μ; aggregates present in the kernel largely disintegrated in manufacture; hilum central, small; polarization cross distinct, no marked play of color with selenite plate.

Description is of commercial rice starch.

[1] Food Products, New York, 1924.
[2] Z. Spiritus-Ind. 1901, 24, 502.

Chemical Composition.—König's analysis [1] of rice starch gave: water 13.71; protein 0.81; fat, nitrogen-free extract, and fiber 85.18; and ash 0.30 per cent.

KUDZU STARCH.—The root tubers of *Pueraria hirsuta* Schneider (*P. thunbergiana* Benth.), a leguminous vine much grown in Japan and China, are rich in starch resembling that of cassava root. Starch made from the root is used as food and medicine.

Microscopic Structure (Plate II, Fig. 15).—Grains round, kettledrum-shaped, polygonal, resembling cassava starch but individuals with more than one truncation more numerous, diameter up to 35 μ, in some specimens only 16 μ; hilum distinct, central or somewhat excentric; rings distinct; polarization cross distinct.

Description is of starch from tubers furnished by Dr. Mantaro Kondo, Director of Ōhara Institute, Kuraschiki, Japan, by New York Botanical Garden, Bronx, and by Dr. W. E. Safford, Bureau of Plant Industry, Washington, D. C.

CASSAVA STARCH is produced by two of the world's great food plants, the bitter cassava, *Manihot utilissima* Pohl, and the sweet cassava, *M. aipi* Pohl (*Euphorbiaceæ*). Other names are Bahia, Rio, or Para arrowroot. The agglutinated product is common tapioca or manioca. In Brazil, the bitter cassava is used for starch production, the hydrocyanic acid present in the fresh moist root being removed by washing and drying. In Florida, sweet cassava is utilized, the product being well adapted for sizing cotton cloth.

Microscopic Structure (Plate II, Fig. 16).—Large grains mostly kettledrum- and flask-shaped, less often with two or more truncations, appear round when resting on truncated surface, diameter up to 35 μ; hilum usually central, distinct; rings evident but not distinct; polarization cross very distinct. Both large and small grains sometimes occur in aggregates.

Description is of several specimens exhibited at Centennial Exposition, Philadelphia, 1876.

Chemical Composition.—Balland [2] reports 2 analyses as follows.

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Foreign	12.80	Trace	0.20	86.88	0.08	0.04
French	16.00	0.45	0.15	82.95	0.00	0.45

[1] Landw. Vers.-Stat. 1897, **48**, 98.

[2] J. pharm. chim. 1898, **7**, 328.

SWEET POTATO STARCH.—This product is made in Brazil from the tuberous root of *Batatas edulis* Chois. or *Ipomœa Batatas* Lam. (*Convolvulaceæ*) and is known as Brazilian arrowroot, also as Batata starch. Wiesner [1] found 10 per cent of sugar and only 9 per cent of starch in the tuber grown in the tropics, but only 3 to 4 per cent of sugar and as much as 15 per cent of starch in tubers grown in the subtropics.

Microscopic Structure (Plate II, Fig. 17).—Large grains similar to those of cassava but larger, forms with more than one truncation common, diameter up to 50 μ; hilum distinct, more excentric than cassava, excentricity seldom greater than 1 : 2; rings usually indistinct; polarization cross striking. Small grains like large in form. Rosettes of calcium oxalate present.

Description is of starch exhibited at the Centennial Exposition, Philadelphia, 1876, and direct from the root.

TACCA STARCH or Williams' arrowroot, is made from the root of *Tacca pinnatifida* Forst. (*Taccaceæ*), a plant growing, according to Safford,[2] in the Malay Archipelago, throughout Polynesia, and Burma. The root also is eaten as a vegetable.

Microscopic Structure (Plate II, Fig. 18).—Grains like cassava starch but perhaps a trifle larger. Raphides commonly present.

The material examined was kindly furnished by Lt.-Col. Sir David Prain, I.M.S., M.B., LL.D., etc., Director of the Royal Botanic Gardens, Kew, England, and agrees with that described by Blyth and by Planchon and Juillet whereas that described by Tschirch and Oesterle and by Hartwich is of the Bermuda arrowroot type. Negotiations with Dr. W. E. Safford to secure authentic material from Guam, of which he was formerly Governor, were interrupted by his sudden death.

ARUM STARCH.—Portland arrowroot is the commercial starch obtained from the corms of *Arum maculatum* L., *A. esculentum* L., *A. italicum* Lam., and possibly other species of *Arum* (*Araceæ*).

Microscopic Structure (Plate II, Fig. 19).—Large grains polygonal, truncated, often in small aggregates, diameter up to 22 μ; hilum central, with clefts; rings usually indistinct. Small grains often in aggregates. Raphides present.

Description is of starch direct from corm of *A. maculatum*.

Chemical Composition.—Pantanelli [3] gives the following analyses, respectively, of two- and three-year-old corms of " Gigaro " (*A. italicum*) which grows wild in enormous quantities in Italy: water 65.31 and 64.67, protein 1.75 and 1.50, pure protein 0.81 and 0.50, reducing sugars

[1] Rohstoffe des Pflanzenreiches.

[2] Useful Plants of Guam, Contrib. U. S. Herb., Washington, 1905, **9**, 380.

[3] Staz. sper. agr. ital. 1918, **51**, 69.

0.15 and 0.03, dextrin 0.46 and 0.36, starch 20.70 and 21.74, and ash 0.53 and 0.58 per cent. He states that the roots of "Cuckoopint" (*A. maculatum*) are too small to be of economic value.

No analysis of the commercial starch is available.

ARRACACHA or **APIO STARCH.**—The fleshy branching roots of *Arracacia esculenta* DC. (*Umbelliferæ*) in northern South America are prized as a vegetable. From the roots is prepared an edible starch.

Microscopic Structure (Plate II, Fig. 20).—Large grains polygonal or truncated, obviously from aggregates, or round, diameter up to 35 μ, mostly less than 25 μ; hilum central when evident; rings one or two. Small grains like large.

Description is of starch exhibited at Centennial Exhibition, Philadelphia, 1876.

BEAN TREE STARCH.—The seed of *Castanospermum australe* Cunn. (*Leguminosæ*) or bean tree is rich in starch which in New South Wales is extracted on a commercial scale.

Microscopic Structure (Plate II, Fig. 21).—Resembles cassava starch but grains are smaller, not of usual leguminous type. Grains round, truncated, or polygonal, diameter up to 22 μ; hilum central, distinct; rings evident; polarization cross distinct.

Description is of starch from seeds furnished by the late Dr. J. H. Maiden, F.L.S., Director of the Botanic Gardens, Sydney, Australia.

TARO STARCH.—This starch is obtained from the corms and cormels of *Colocasia antiquorum* Schott (*Araceæ*).

Microscopic Structure (Plate II, Fig. 22).—Grains polygonal, kettle-drum-shaped, or rounded, diameter up to 9 μ; other characters not noticeable in grains of such small size. In some corms maximum diameter 4 μ.

Description is of starch from corms supplied by Dr. R. A. Young, Plant Introducer, Bureau of Plant Industry, Washington, D. C.

YAUTIA STARCH.—The yautias are members of the aroid group (*Araceæ*). The starch of *Xanthosoma caracu* is here described.

Microscopic Structure (Plate II, Fig. 23).—Grains polygonal, kettle-drum-shaped, or rounded, diameter up to 20 μ; hilum central, evident in larger grains; polarization cross indistinct; aggregates present, also calcium oxalate raphides.

Description based on starch from corms supplied by Dr. R. A. Young, Plant Introducer, Bureau of Plant Industry, Washington, D. C.

YAM BEAN STARCH.—The fleshy turnip-like root of the yam bean, *Pachyrhizus erosus* Urban = *P. angulatus* Rich. (*Leguminosæ*), a common Chinese vegetable, owes its nutritive value in large part to starch. Commercial starch is made from the root in China.

Microscopic Structure (Plate II, Fig. 24).—Large grains polygonal or truncated, diameter up to 24 μ; hilum central, often with clefts; rings evident. Small grains more numerous than large, of various sizes and shapes.

Description is of starch from root bought in Chinese Quarter, New York City.

WHEAT STARCH is made on the Continent from common wheat (*Triticum sativum vulgare*), although, according to Wiesner,[1] spelt (*T. sativum spelta*) yields starch of excellent quality and English wheat (*T. sativum turgidum*) has the advantage of a larger yield. Macaroni wheat (*T. sativum durum*) is said to be unsuited for the purpose because of the horny structure of the endosperm, but doubtless could be used if a process similar to that developed in the maize industry were followed.

The primitive process of soaking the grain until soft, crushing, and elutriating yields a gray product containing much gluten. By the fermentation process organic acids are developed in which the gluten dissolves. The Martin process is in substance like that employed in determining gluten, namely, washing the dough on sieves with continual kneading, thus securing as a by-product gluten for which there is a demand as a diabetic food and for other purposes.

Microscopic Structure (Plate III, Fig. 25).—Large grains lenticular (elliptical when on edge), diameter commonly 28 to 40 μ, rarely 50 μ; hilum central, seldom with clefts; polarization cross indistinct (Fig. 37), no play of colors with selenite plate. Small grains globular or polygonal.

Description is of starch direct from grain.

Chemical Composition.—In 14 samples of wheat starch made by various processes Saare [2] found:

	Water	Protein	Fat	Ash	Acidity *
	%	%	%	%	cc.
Min	9.87	0.15	0.04	0.09	0.0
Max	15.30	0.52	0.11	0.39	3.0

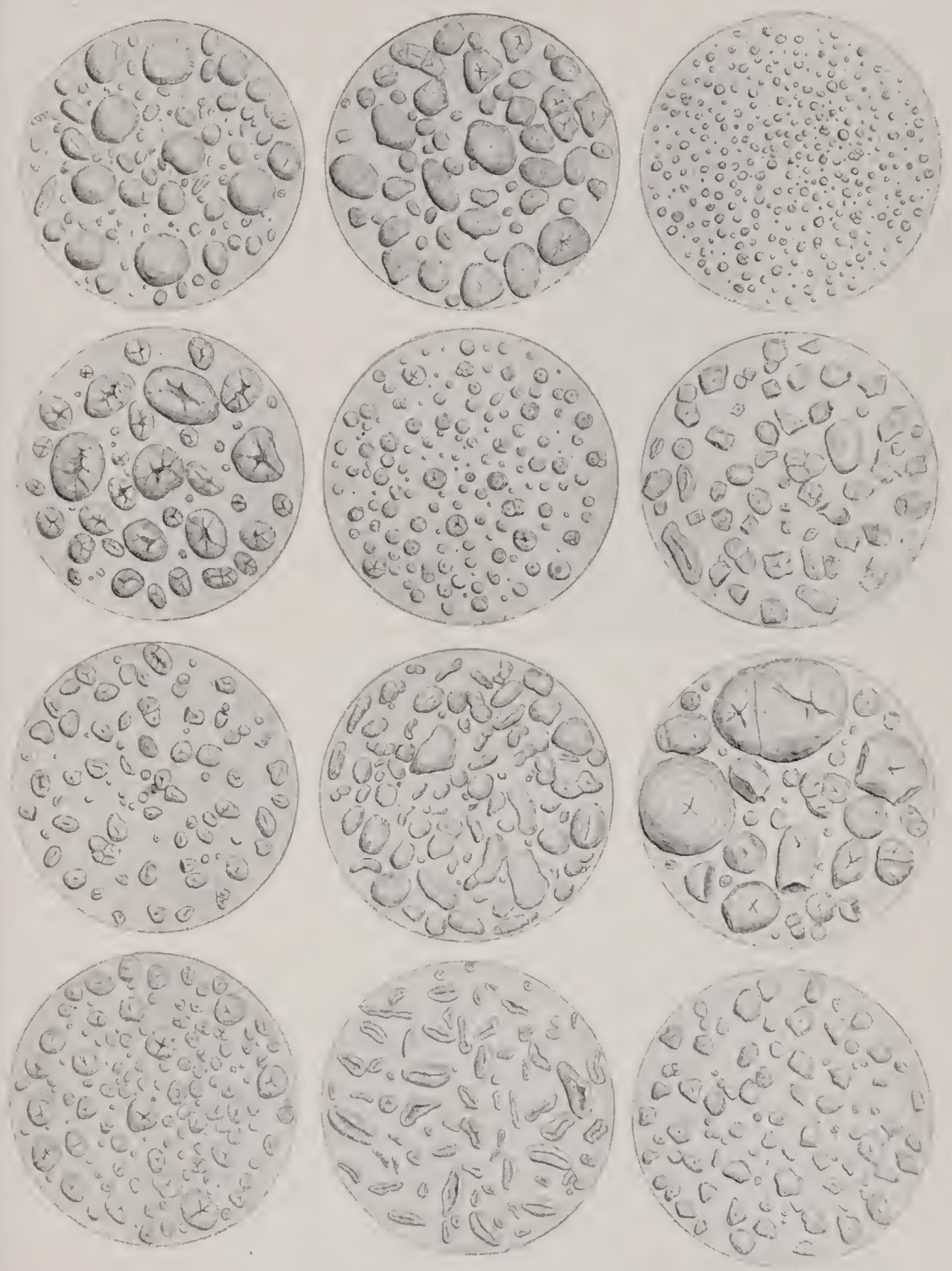
* Cc. N/10 alkali per 100 grams of starch.

HORN CHESTNUT STARCH.—The seed of *Trapa bispinosa* Roxb. (*Trapaceæ*), sold in the Chinese Quarters of American cities as a curiosity, is rated by some as one of the five food grains of China. A

[1] Loc. cit.

[2] Z. Spiritus-Ind. 1901, **24**, 502.

PLATE III



Commercial Starches. ×160. (A.L.W.)

FIG. 25 Wheat
28 Bean
31 Lotus Seed
34 Arrowhead

FIG. 26 Horn Chestnut
29 Pachira
32 Warabi
35 Mango

FIG. 27 Breadfruit
30 Araucaria
33 Coontie
36 Water Chestnut

starch found in an invoice shipped to a Chinese merchant in Chicago long baffled the writers until its identity with that of the horn chestnut was established.

Microscopic Structure (Plate III, Fig. 26).—Large grains elliptical, rounded-triangular, or quadrilateral, often characterized by excrescences on one or both sides, length up to over 40 μ; hilum usually central occasionally with excentricity of 1 : 2 to 1 : 3, in dried seed often with clefts, less often in fresh seed; rings distinct in nearly true circles; polarization cross very distinct.

Fig. 37.—Starch Grains Viewed with Polarized Light. I potato. II curcuma. III wheat. IV bean. ×300 (A.L.W.)

Description is of sample referred to above and starch direct from the seed.

BREADFRUIT STARCH.—Both the seed and pericarp tissues of the breadfruit, *Artocarpus incisa* L., as well as the Jack fruit, *A. integrifolia* Forst. (*Moraceæ*), contain starch but with different microscopic characters.

Microscopic Structure.—Pericarp starch grains (Plate III, Fig. 27) rounded, less often angular, sometimes in aggregates, diameter up to 10 μ; hilum and rings not usually evident; polarization cross indistinct. Seed starch grains both round or truncated, diameter up to 18 μ; hilum very distinct.

Description is of starch from fruit furnished by Prof. H. J. Cowles, University of Porto Rico.

BEAN STARCH.—Although the common bean (*Phaseolus vulgaris* L.) is seldom if ever used for starch manufacture, a number of authors describe and picture it as a commercial starch. It is here included because it is representative of the leguminous class.

Microscopic Structure (Plate III, Fig. 28).—Large grains elliptical or kidney-shaped, length up to 60 μ; hilum appears to be elongated with radiating clefts; rings present; polarization cross (Fig. 37) really a double cross forming two V's joined by a line. As noted in the introduction to this chapter, what appear to be individual grains are aggregates of two or more members, hence the double cross. Other leguminous starches with double grains are described under Vegetables, Volume II.

Description is of starch direct from the seed.

Chemical Composition.—Analyses of four types of bean starch, reported by Adolph,[1] show:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
From green beans (Yang-fen)	2.85	1.53	0.19	94.23	0.53	0.67
Strips (Kan-fen)	10.41	0.65	0.20	88.10	0.36	0.28
Sheets (Fen-p'i)	16.92	0.61	0.06	81.50	0.75	0.15
——— (Fen-t'i)	0.03	3.09	0.16	96.02	0.31	0.34

PACHIRA STARCH.—The seed of *Pachira aquatica* Aubl. (*Bombaceæ*), grown in Guiana, contains a starch said to be extracted on a small scale.

Microscopic Structure (Plate III, Fig. 29).—Grains mostly round, less often truncated or in aggregates, diameter up to over 20 μ (some up to 30 μ apparently swollen); hilum central, often with clefts; rings evident; polarization cross distinct but not pronounced.

Description is of starch from seeds furnished by the late Dr. W. E. Safford, Bureau of Plant Industry, Washington, D. C.

ARAUCARIA STARCH.—In Brazil, starch is made from seeds of *Araucaria braziliana* Lamb (*Pinaceæ*) and perhaps other species.

Microscopic Structure (Plate III, Fig. 30).—Grains quadrilateral, triangular, and kettledrum-shaped from rod-shaped aggregates, also elliptical or much elongated, diameter up to 40 μ; hilum central or somewhat excentric, distinct; rings usually distinct; polarization cross markedly distinct.

Description is of starch exhibited at the Centennial Exposition, Philadelphia, 1876, and from seeds furnished by New York Botanical Garden.

LOTUS SEED STARCH.—The seed as well as the rhizome (see above) serves for the manufacture of starch.

Microscopic Structure (Plate III, Fig. 31).—Grains ovate, rounded, spindle-shaped, kidney-shaped, or truncated, some occurring in aggregates, diameter up to 30 μ; hilum central or somewhat excentric with clefts; rings and polarization cross indistinct.

Description is of starch from seeds of Chinese importer.

WARABI STARCH.—The common brake, *Pteridium aquilinum* (L.) Kny = *Pteris aquilina* L. (*Polypodiaceæ*), is a cosmopolitan plant with a rhizome from which warabi starch is obtained.

[1] Philippine J. Sci. 1926, **30**, 287.

Microscopic Structure (Plate III, Fig. 32).—Large grains elliptical, irregularly elongated, length up to 45 μ; hilum and rings not usually evident. Medium and small grains elongated or in rod-shaped aggregates.

Description is of starch from Japan furnished by New York Botanical Garden.

COONTIE STARCH.—According to H. J. Webber,[1] both *Zamia floridana* DC. (coontie) and *Z. pumila* L. (*Cycadaceæ*) grow abundantly in Florida. Starch from the former has been made commercially and marketed under the name of Florida arrowroot.

Microscopic Structure (Plate III, Fig. 33).—Large grains truncated, often in aggregates of two members, diameter up to 80 μ or more; hilum central or excentric 1 : 2 to 1 : 3, often with clefts; rings indistinct, polarization cross strong. Medium and small grains similar to large in form.

Description is of sample from New York Botanical Garden.

Chemical Composition.—The dried rhizome, as analyzed by Clevenger,[2] contains: water 7.73, protein 6.17, fat 0.63, nitrogen-free extract 71.23, fiber 9.23, and ash 5.01. Analyses of the starch are not at hand.

ARROWHEAD STARCH.—Blasdale [3] states that the Chinese make starch from the tubers of *Sagittaria latifolia* Willd., a plant belonging to the *Alismaceæ* family.

Microscopic Structure (Plate III, Fig. 34).—Large grains round, oval, or rounded angular, diameter up to 36 μ; hilum central or nearly so with clefts; rings evident; polarization cross evident but not striking.

Description is of starch from tubers from the Chinese Quarter of New York City; it agrees with that of Blasdale.

MANGO STARCH.—The seed of *Mangifera indica* L. (*Anacardiaceæ*) contains a starch quite distinct from any other here described.

Microscopic Structure (Plate III, Fig. 35).—Large grains elongated, spindle-shaped or kidney-shaped, length up to 50 μ; true hilum central as shown by polarization cross, false hilum elongated, nearly as long as grain; rings distinct; polarization cross of two lines crossing at hilum, not of two V's joined by a line as in common garden legumes, hence grains are simple and not two consolidated grains.

Description is of starch direct from seed.

WATER CHESTNUT STARCH.—Corms of *Eleocharis tuberosa* (*Cyperaceæ*), a familiar Chinese vegetable and ingredient of chop suey, yield a starch with unique histological characters.

[1] U. S. Dept. Agr., Bur. Plant. Ind., 1902, Bul. **2.**

[2] J. Am. Pharm. Ass. 1921, **10,** 837.

[3] U. S. Dept. Agr., Off. Exp. Sta., 1899, Bul. **68.**

Microscopic Structure (Plate III, Fig. 36).—Large grains rounded triangular, quadrangular, pentagonal, spindle-shaped or irregular, up to 27 μ; hilum central, sometimes with clefts; rings indistinct; polarization cross indistinct.

Description is of starch from corms sold in the Chinese Quarter of New York City.

SEEDS OF THE GINKGO FAMILY

(Ginkgoaceæ)

One species, a diœcious tree, bears a seed with characters of a fruit.

GINKGO

Ginkgo biloba L. = *Salisburya adiantifolia* Sm.

The ginkgo or maiden-hair tree, a native of Japan and the sole survival of numerous related species that thrived in the geological past, is widely different from all other plants. It is the only species of the only genus of the only family of the order *Ginkgoaceæ*.

The pulp of the seed yields edible oil, the seed, a starchy-oily food.

MACROSCOPIC STRUCTURE.—Fertilization of the naked ovule is by motile spermatozoids from a male tree, not pollen, and the embryo develops after the seed drops from the tree. The *seed* has the general appearance of a small plum. It is somewhat longer than broad, yellow with a bloom, and foul smelling. The pointed-ovoid, rimmed *stone* has a smooth white shell (not endocarp) and an exceedingly thin brown inner skin adherent to the kernel at the point of attachment. The bulk of the kernel consists of endosperm within which is the narrow embryo, with two cotyledons and radicle, reaching 1 cm. in length.

MICROSCOPIC STRUCTURE.—Kondo [1] has studied the histology of this seed, his results being of particular interest because of the other peculiarities of the species.

The Outer Spermoderm (" fruit flesh ") consists of (1) *outer epiderm* of rounded polygonal cells with very thick cuticle (25 μ) and brown granular contents, also sunken stomata, and (2) *parenchyma*, in the outer part with occasional crystal rosettes, in the inner part interspersed with somewhat larger cells (green with sodium hydroxide) and tangentially elongated oil sacs (up to 2 mm.) with yellow-brown contents changing to pink with the alkali.

[1] Landw. Vers.-Stat. 1913, **81**, 444.

The *oil sacs* are surrounded by thin-walled polygonal cells.

The Inner Spermoderm consists of (1) *shell*, a mass of elongated stone cells arranged transversely in the outer and longitudinally in the inner portion, and (2) *skin*, a brown parenchyma tissue with here and there spiral and pitted cells.

The lumen of the *stone cells* is reduced to a mere line except midway between the ends, where it is enlarged just enough to contain a small refractive lump.

Perisperm.—Kondo considers that the thin white lining of the skin is perisperm.

Endosperm.—A rich store of *starch* (Fig. 38) is present in the polygonal cells. The simple grains are homogeneous with little evidence of hilum or rings, and the aggregates have indistinct lines separating the component grains. Polarized light distinguishes simple grains from aggregates and locates the position of the hilum. The aggregates of two to four grains reach 35 μ; the round or elliptical simple grains, somewhat less.

FIG. 38.—Ginkgo. Starch from endosperm. ×130. (A.L.W.)

Embryo.—Starch like that of the endosperm but with somewhat smaller grains is present in the fully developed embryo.

CHIEF STRUCTURAL CHARACTERS.—Seed fruit-like. Spermoderm with fruit flesh, stone, and inner skin. Endosperm bulky. Embryo axial, elongated, narrow.

Outer spermoderm with cells staining green with sodium hydroxide and elongated oil sacs staining pink; inner spermoderm of colorless elongated stone cells, each containing a refractive body, and brown parenchyma. Endosperm and embryo with simple rounded starch grains and aggregates of two or more grains.

CHEMICAL COMPOSITION.—The pulp of the ginkgo fruit has an offensive butyric odor but doubtless has real food value when properly prepared. According to Bechamp,[1] it contains fatty acids of the aliphatic series from formic to caprylic.

The seed, although bitter, after cooking is prized by the Chinese as a digestant.

Analyses are given below of the shelled seed by Blasdale [2] and by Langley,[3] the material in the former case being from a Chinese merchant

[1] Compt. rend. 1864, **53**, 135.

[2] U. S. Dept. Agr., Off. Exp. Sta., 1899, Bul. **68**, 44.

[3] J. Am. Chem. Soc. 1907, **29**, 1513.

in San Francisco and in the latter case from Hon. Wu Ting Fang, ex-minister from China to the United States:

Composition of Ginkgo Kernels

	Water	Protein	Amides	Fat	Starch	Sucrose	Pentosans	Other carbohydrates	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Blasdale....	47.34	5.90	0.72	0.81	33.90	3.58	.....	5.58	0.88	2.00
Langley....	15.7	11.0	.....	2.4	57.2	.....	1.3	8.7	0.8	2.9

Furuichi [1] corroborates Langley's results in essential details.

Proteins.—Furuichi [1] proposes the name *ginkgoin* for the globulin, the nitrogen of which constitutes 60 per cent of the total nitrogen of the seed. It contains a large amount of tryptophane. Other proteins present are an albumin, a prolamine, and a glutelin. Determination of the isoelectric point by adding a drop of hydrochloric acid to the alkaline solution showed that the point of maximum surface tension and the maximum turbidity agree approximately with each other. The globulin required the least amount of hydrochloric acid and the glutelin the largest, the albumin being intermediate.

Mineral Constituents.—An analysis of the ash of the seed by Furuichi [1] follows:

K_2O	Na_2O	CaO	MgO	Fe_2O *	P_2O_5	SO_3	SiO_2
%	%	%	%	%	%	%	%
40.6	8.4	4.8	7.7†	3.7	21.6	8.3	4.9

* Includes Al_2O_3.

† Obtained by difference; no figures in abstract.

[1] Bul. Tottori Higher Agr. School, 1928, **1**, 105; Chem. Abs. 1929, **23**, 2196.

CEREALS AND WEED SEEDS OF THE GRASS FAMILY

(Gramineæ)

True cereals, or cereals in the narrow sense as here used, may be defined as grain produced by members of the grass family. Although, strictly speaking, the term is applied to the cultivated species, for convenience, as well as to conform to botanical classification, such other species of the family as grow as weeds in grain fields and yield fruits which find their way into the threshed grain are also included. Some of these wild forms are closely related to the cultivated species or are varieties of the same species. The plants themselves, as well as the grain, are known as cereals.

In the still broader sense, cereals include the buckwheats. This common usage seems logical if the general composition of the grain and its utilization in bread foods alone are considered. Since, however, the species belong to a widely separated family in the dicotyledonous group they are given a separate section as are starchy seeds of other families.

CLASSIFICATION.—The grasses are divided into thirteen tribes. Representatives of at least nine of these tribes are cereals furnishing important grains both for the human race and cattle, and of the remaining tribes representatives of three are well-known forage grasses (which see). A list of the tribes with the most important genera of cereals and forage grasses follows:

Classification of Cereals

I. *Maydeæ.—Zea* (maize), *Coix* (Job's tears), *Euchlæna* (teosinte[1]).
II. *Andropogoneæ.—Sorghum* (broom corn, sugar sorghum, Kaffir corn, durrha, milo maize).
III. *Zoysieæ.—Hilaria* (black grama,[1] galleta[1]).
IV. *Tristegineæ.*—Unimportant tropical species.
V. *Paniceæ.—Panicum* (common millet, barnyard millet), *Setaria* (German millet, green foxtail,[2] yellow foxtail [2]), *Pennisetum* (pearl millet).
VI. *Oryzeæ.—Oryza* (rice), *Zizania* (wild rice).
VII. *Phalarideæ.—Phalaris* (canary seed).
VIII. *Agrostideæ.—Agrostis* (red top,[1] etc.), *Phleum* (timothy [1]).
IX. *Aveneæ.—Avena* (oats, wild oats [2]).
X. *Chlorideæ.—Eleusine* (coracan).

XI. *Festucæ*.—*Bromus* (chess[2]), *Eragrostis* (teff), *Glyceria* (manna grass), *Poa* (June grass,[1] etc.), *Festuca* (fescues [1]).

XII. *Hordeæ*.—*Triticum* (wheat, spelt, emmer, einkorn), *Secale* (rye), *Hordeum* (barley), *Lolium* (darnel[2]).

XIII. *Bambuseæ*.—*Bambusa* and other species of bamboo.

[1] Forage grass.
[2] Weed.

COMPARATIVE MACROSCOPIC STRUCTURE.—The botanical classification of the grasses, including the cereals, is based largely on characters of the inflorescence with little regard to the ripe fruit or caryopsis, commonly known as the kernel, which for the food specialist is of chief importance. Since the floral envelopes persist to maturity as chaff and often closely invest the kernel, their structure is important as a means of identification of the grain.

Flower.—Unlike most higher plants, the cereals lack conspicuous and variously colored calyx (sepals) and corolla (petals). The inflorescence is either dense, in heads or spikes, or loose, in panicles or racemes, made up in both cases of *spikelets* borne on a rachis, each spikelet with one or more flowers. The spikelet is subtended by two *empty glumes*, and the flowers are borne in the spikelet on a short axis or *rachilla*, each in the axil of a *flowering glume* which usually clasps over the edges of a *palet*, both more or less closely enveloping the grain at maturity. *Lodicules* are small papery scales, two of which occur at the base of the flower within the flowering glume. In some few species a third occurs within the palet. Normally three *stamens* are present which disappear during ripening. The *pistil* has one ovary and the ovary one ovule which ripens into the single seed.

Chaff is a convenient collective term for the empty glumes, flowering glumes, palet, lodicules, bristles, and rachilla of the mature spikelet. It should be borne in mind that the chaffy parts are modified leaves usually resembling much more closely true leaves than do the showy floral envelopes of most other families. At the flowering stage they are usually green, but on ripening they become yellow or brown. Chaff is of small food value, being scarcely better than straw as animal food and because of its harshness entirely unsuited to the human stomach. Certain forms of chaff, such as rice hulls, are too harsh even for animals.

The term chaffy is applied to cereals when the flowering glume and palet, less often also the empty glumes, tightly invest the fruit and are removed with it from the straw on threshing. Most varieties of oats and barley, also rice, common, German, and barnyard millets, canary seed, the foxtails, chess, and darnel are chaffy, enveloped only by the

flowering glume and palet, whereas chaffy wheats (spelt, emmer, and einkorn), broom corn, sugar sorghum, and pod maize are enveloped also by the empty glumes, and teosinte, in addition to flowering glumes and palets, by a boat-shaped joint of the rachis.

Naked cereals are those in which the fruit readily separates on threshing, leaving the chaff with the straw or as a light impurity that blows away on winnowing. Wheat and rye, some varieties of barley, common varieties of maize, also Job's tears, durrha, Kaffir corn, milo maize, teff, coracan, and pearl millet are naked.

Empty Glumes.—Normally there are two empty glumes, one on each side of the spikelet. They usually remain with the straw on threshing even if the grain is chaffy, but in some cases they are attached to the grain as noted above. As a rule, the empty glumes are more characterless than the flowering glume and palet. They are blunt or pointed or occasionally short-awned, and varied as to venation. In some species they are thick and horny, in others thin and papery.

The *flowering glume* is commonly convex and, although often several nerved, lacks the pronounced keels and wings such as occur on the palet. In most species it is thick and horny; in some few, notably maize and sorghum, it is membranous. It may be smooth (oats, barley, spelt, emmer, einkorn, canary seed, common millet) or rough (rice, wild rice, German millet, foxtails, manna grass). An awn, more or less twisted, may or may not be present. Even the same species may have awned and awnless varieties.

Palet.—The inner envelope of each flower, the palet, is generally characterized by two pronounced lateral nerves, often forming two keels. In oats the keels have a comb edge of stiff hairs. The two wings, forming the tissue between the keels and the edges, often differ in texture from the middle portion. Canary seed has a central hairy keel midway between the two nerves.

The *lodicules* are inconspicuous, of thin, membranous texture.

The *rachilla*, forming the axis of the spikelet, is more or less zigzag, of hard texture.

Bristles with saw-like barbs occur at the base of each spikelet of foxtails.

Pericarp.—The dry fruit coat or pericarp of the cereals forms the outer bran tissue which, except in coracan, is attached throughout to the spermoderm of the seed.

In wheat, spelt, emmer, einkorn, rye, barley, and oats the pericarp bears a tuft of *hairs* at the apex. In these cereals, also in chess, darnel and manna grass, the fruit has a *groove* or cleft on the ventral side extending well into the center. Wild rice has a narrow groove over the embryo

extending beyond it nearly the whole length of the narrow cylindrical fruit, and maize and Job's tears have a broad groove over the embryo. If there is no pronounced groove over the embryo, a sunken or wrinkled area usually marks its position.

Spermoderm and **Perisperm** form layers too thin to show macroscopic characters. The *raphe* is best studied microscopically.

Endosperm forms the greater part of the seed. It is rich in starch (or soluble carbohydrate in sweet or waxy maize) except for the aleurone layer. Two forms of starchy endosperm are evident to the naked eye: *horny* and *floury*. One alone may be present but usually both, the relative proportion varying with species, variety, or individual. For the most part, the horny portion is toward the periphery, the floury more central, without sharp demarcation. Both contain starch as the chief constituent and protein in smaller amount. Taken as a whole, the water-free endosperm (exclusive of the aleurone layer) contains up to about 90 per cent of starch and from a fifth to a tenth as much protein. The protein is most abundant in the horny tissue, acting as a cement in which the starch is embedded.

Embryo.—In striking contrast is the composition of the embryo. A drop of iodine solution suffices to show that it contains no starch, but the presence of an abundance of *oil* is shown by squeezing.

The general structure of the embryo of the larger cereals, such as maize and wheat, is evident in longitudinal section under a lens. The *plumule* is directed upward, the *radicle* or radicles downward, the two being connected by the *hypocotyl* which in turn is connected on one side with the *scutellum* (cotyledon) extending the length of the embryo adjoining the endosperm. Further details of the large seeds and all details of the small seeds require the magnification of the compound microscope.

COMPARATIVE MICROSCOPIC STRUCTURE.—Kudelka [1] is entitled to special credit as the pioneer in this field. All the later authors on the microscopy of foods have devoted special attention to the group.

Cereals are characterized by the structure of the monocotyledonous leaf-type chaff, of the thin dry pericarp (adherent except in coracan to the seed) with analogous tissues more or less well developed in the different species, of the thin spermoderm and perisperm, of the endosperm with outer starch-free aleurone cells and inner parenchyma with starch grains of various types, and of the starch-free tissues of the monocotyledonous embryo. In buckwheats, which closely resemble the cereals in the

[1] Ueber die Entwicklung und den Bau der Frucht- und Samenhaut unserer Cerealien, Berlin, 1875.

structure of the endosperm, the pericarp is not grown to the seed and is of radically different structure; furthermore, chaff is lacking and the embryo is dicotyledonous.

Empty Glumes in most cereals remain with the straw or if detached are removed on winnowing. Often they are of thinner texture than the flowering glume, owing to the absence or underdevelopment of the hypoderm; in maize, however, they are thick and horny except on the end, where they are papery.

The *outer epiderm* in maize is made up of characteristic isodiametric or somewhat elongated cells, some with thick walls and deep pits, others with thinner, non-porous walls. The latter are hair scars or cells accompanying them. Quite as characteristic are the wavy-walled cells and thin hairs of the thin tips.

The Flowering Glumes represent the common type of chaff, being leathery or horny (except in maize, Job's tears, and sorghums) and made up of four layers: (1) *outer epiderm* consisting of wavy-walled cells frequently interspersed with round cells and twin cells (one often crescent-shaped) and in parts with stomata and hairs ; (2) *hypodermal fibers*; (3) *mesophyl* of spongy parenchyma or less often simple parenchyma; and (4) *inner epiderm* of elongated, thin-walled polygonal cells interspersed in parts with stomata and hairs.

The *outer epiderm* in spelt, emmer, einkorn, barley, oats, pearl millet, darnel, teff, and chess consists of cells with wavy, more or less thickened walls, which are commonly much elongated and interspersed with round cells and twin cells, also in parts with stomata and hairs of various types; in canary seed it consists of long cells with wavy walls so thick as to appear straight; in rice, in common, barnyard, the German millets, and in green and yellow foxtails, on the body of the flowering glume, it consists of broad isodiametric or slightly elongated cells with deeply sinuous (plaited) walls, round cells and twin cells being few or absent. The outer epiderm in maize, Job's tears, and sorghums has elongated cells with thin wavy walls.

Hypodermal fibers are practically the same in all the cereals except that the thickness of the layer and the degree of thickening of the walls vary. In parts they bear excrescences on the side fitting into corresponding depressions in neighboring fibers or cells.

Mesophyl.—Two types of spongy parenchyma occur: (1) quadrilateral cells with intercellular spaces so small as not to destroy the quadrilateral appearance (barley, spelt, emmer, einkorn, rice, sorghum); and (2) cells which, although perhaps built on the quadrilateral plan, have such large intercellular spaces as to appear star-shaped. This form is characteristic of oats. In common, barnyard, and German millets and

green and yellow foxtails the mesophyl is ordinary parenchyma without any considerable number of intercellular spaces.

The *inner epiderm* usually consists of cells with thin straight walls, stomata, and often hairs, but is not conspicuous and seldom characteristic.

Palet.—As a rule, the central portion of the palet between the two lateral nerves or keels closely resembles the flowering glume in structure as well as thickness and texture; the wings, however, are generally more delicate, owing partly to the less robustly developed *hypoderm* or its absence, and partly to the lesser thickening of the walls of the *outer epiderm* cells.

In common and German millets and the foxtails the outer epiderm cells of the wings are much more elongated and the walls much less sinuous than in the middle; also, as is evident to the naked eye, they are smooth and lustrous, whereas in the middle portion, as on the whole surface of the flowering glume except in common millet, they are roughened.

Stiff hairs occur on the palet keels of oats, chaffy wheats, chess, and darnel, but are absent on the palet keels of barley, common and German millets, and the foxtails. In canary seed, greatly thickened hairs occur on a keel midway between the two nerves. The palet of maize, the sorghums (broom corn and sugar sorghum) and Job's tears is of membranous structure and without keels.

Lodicules.—These are papery in texture and characterless in structure except for the *hairs* which in barley are of various forms, both long (up to 1300 μ) and short, thick- and thin-walled, simple and branching.

Rachis and Rachilla.—The joint of the rachis attached to each spikelet of the chaffy wheats, also the joint of the rachilla attached at the side of each chaffy grain of darnel and chess and the rachilla of an abortive flower on the palet side of barley, are similar in their structural elements to the thick chaff. Stiff *hairs* of large size characterize the rachilla of barley.

Pericarp.—Little if any resemblance exists between the pericarp and the leaves of the grasses to which it corresponds morphologically. Five distinct layers are present in some few cereals, but usually only four are evident and sometimes less.

The nomenclature here adopted differs from that of most authors in that the layer immediately beneath the epicarp and resembling it is termed hypoderm as proposed by A. Meyer, and not mesocarp, the latter term being reserved for the parenchyma beneath it, containing starch in unripe sorghums and perhaps other cereals, which may persist up to maturity. The layers are: (1) *epicarp* or outer epiderm, usually of

longitudinally elongated cells (in rice, wild rice, and manna grass transversely elongated) except at the apex, where they are isodiametric and may be interspersed with hairs; (2) *hypoderm* of one to several layers resembling the epicarp in form and arrangement; (3) *mesocarp* of thin-walled cells usually so compressed as not to be evident at maturity; (4) *cross cells*, so called because of their transverse arrangement, forming a close or loose tissue; and (5) *endocarp* consisting of isolated vermiform cells, longitudinally arranged, known as *tube cells*, or of spongy parenchyma or intermediate forms.

Epicarp.—The epicarp cells of cereals, excepting only those of rice, wild rice, and manna grass, are longitudinally elongated over the body of the grain and isodiametric at the apex. Although often arranged end to end in rows, they are never, like the cross cells, side by side in rows, that is, *they break joints.* The walls are distinctly beaded in wheat and maize, less distinctly in spelt and sorghum, indistinctly in rye, emmer, einkorn, oats, and darnel, and without beads in common, barnyard, and German millets, foxtails, canary seed, and chess. In sorghums, common, German, and pearl millets, Job's tears, teff, and foxtails the walls are wavy. In pearl millet the walls in addition to being wavy are much thickened with distorted beads. Rice and wild rice are characterized by the transverse elongation of the epicarp cells and the peculiarly and deeply sinuous end walls; manna grass, by the transverse elongation, narrow form, and arrangement side by side in rows. Teff lacks all pericarp tissues other than epicarp.

Hairs up to 1000 μ with broad base occur at the tip of wheat, rye, barley, spelt, emmer, and einkorn, and up to 2000 μ with narrow base on oats. The ratio of thickness of walls to breadth of lumen furnishes a rather uncertain means of distinction.

Hypoderm.—This layer, when present, resembles the epicarp in the elongation and direction of elongation of the cells and the beading of the walls. In oats, common and German millets, foxtails, chess, Job's tears, teff, canary seed, and coracan only traces of the layer at most are present; in wheat, spelt, emmer, einkorn, rye, sorghums, pearl millet, and darnel it is more or less strongly developed; and in maize it forms a thick horny tissue several cells thick.

Mesocarp.—A true mesocarp of distinct thin-walled cells occurs only in the sorghums, where it appears often to escape the obliteration that usually comes with ripening.

Cross Cells.—To the diagnostician these are of first importance. They belong in three classes: (1) elongated cells, arranged side by side in rows, forming a continuous layer with only small intercellular spaces at the ends (wheat, spelt, emmer, einkorn, rye, barley, darnel); (2) vermiform

cells detached or only in loose contact (rice, wild rice, sorghums, common, barnyard, and German millets, foxtails, manna grass, canary seed); and (3) spongy parenchyma or branching vermiform cells (maize, chess, Job's tears, pearl millet).

The distinctness of the beads is of service in distinguishing wheat, spelt, rye, einkorn, and emmer, being most distinct in wheat and least distinct in emmer. Beads are absent in barley and darnel. Barley has a double cross-cell layer.

Endocarp.—Tube cells form this layer in all the species but chess, teff, and coracan, where there is no evident endocarp, and oats, where it appears to be merged with the cross cells. The tube cells may pass into spongy parenchyma. This is well marked in darnel. Numerous tube cells occur in maize, Job's tears, sorghums, rice, wild rice, canary seed, manna grass, common, German, barnyard, and pearl millets; few occur in wheat, spelt, emmer, einkorn, and rye.

Spermoderm.—Only in coracan, where the layer is strongly developed and each cell bears a brown wart, is this coat not adherent to the pericarp. In manna grass also the coat is strongly developed, being about 10 μ thick. In other cereals it is reduced to a thin single or double layer, often of a yellow or brown color. Cross sections usually show but a single or double line; surface preparations show that the cells are longitudinally or diagonally elongated (except in rice and wild rice) with walls so delicate as often to escape notice until after special treatment. If a whole kernel is warmed in dilute sodium hydroxide solution, washed in water containing sufficient acetic acid to destroy the alkalinity, and then scraped, fragments of the spermoderm may be separated which, mounted in chlorzinc iodine solution, are colored deep yellow or brown-yellow.

Perisperm.—None of the cereals has a perisperm developed as a reservoir of reserve material as in black pepper. Most of them, however, have a single or double layer of hyaline cells formed from the body of the ovule outside the embryo sac and therefore entitled to the name.

Only in broom corn, sugar sorghum, brown durrha, and chess is this layer conspicuous both in cross section and surface view. In darnel it forms a double layer; in other cereals, a single layer. In wheat, although evident as a swollen band in cross section, it shows no cellular structure in surface view because of its hyaline nature until treated with sodium hydroxide and stained blue with chlorzinc iodine as described above. This treatment of surface preparations brings out the cells in rice, common, barnyard, and German millets, the foxtails and manna grass, the walls showing in these distinct beads. Although the layer is evident in cross sections of maize and oats as a colorless band, in surface view

no treatment in our experience is effective in showing cellular structure. Only in rice and wild rice are the cells transversely elongated; in the other cereals they are longitudinally or diagonally elongated or else isodiametric.

Endosperm.—All grass fruits, as well as the cereals, consist largely of endosperm with an outer *aleurone layer*, one cell or in barley several cells thick, containing proteins and fat but no starch, and *inner parenchyma* consisting chiefly of carbohydrate, the remainder being largely proteins. In sweet and waxy maize the carbohydrate is largely soluble, giving a red or brown color with iodine; in other cereals it is largely starch.

Aleurone Layer.—The early name gluten cells was abandoned when it was found that gluten was peculiar to wheat and its near relatives, and furthermore, that the bulk of the gluten in these was in the inner portion along with the starch grains. Johannsen [1] advanced the theory that the granular appearance of the contents was due to aleurone or protein grains, hence the name adopted for this layer. This view was generally accepted, and several authors, including Von Höhnel,[2] Berthold,[3] and Lüdtke,[4] considered that the size and other characters of the grains have diagnostic value which Wittmack and also Moeller have disputed. Brahm and Buchwald,[5] in their examination of prehistoric cereals, came to the conclusion that aleurone grains of the usual type do not exist at all in the aleurone layer, the so-called grains being but small fatty lumps enclosed in a protein network.

Our own studies on this point were indecisive when fresh material was used, but an examination of cross sections of wheat mounted in glycerin forty years previously gave unmistakable evidence of the correctness of Brahm and Buchwald's findings. Neither their work nor ours, however, precludes the possibility of minute aleurone grains existing in the threads of the network. Others, as well as ourselves, have observed such grains in a protein network often present in the outer starch cells of cereals, especially broom corn, and it is not improbable that the granular network separating the starch grains of common, barnyard, and German millets, the foxtails, and the sorghums, especially after adding sodium hydroxide as noted below, is due to such grains.

Striking as is the difference between the aleurone and starch cells and their contents, one runs into the other; some of the outer cells of the

[1] Bot. Centralb. 1883, **15**, 305.
[2] Die Stärke und die Mahlprodukte, Kassel und Berlin, 1882.
[3] Z. Warenk. 1883. No. 1.
[4] B. deut. pharm. Ges. 1891, 56. (A. Meyer's Pflanzenpulvern, p. 36.)
[5] Z. Unters. Nahr.-Genussm. 1904, **7**, 12.

inner parenchyma often may have starch replaced by non-starchy contents, whereas the aleurone cells in the groove may contain starch grains. Whether or not the protein contained in aleurone cells is in granular form, there is no conclusive evidence that it differs from that of starch cells.

Credit is due Körnicke and Werner [1] and Benecke [2] for studies of the color located in the contents of the aleurone cells. In wheat and all the chaffy wheats there is no blue coloration. In einkorn there may be a faint blue coloration, and in blue varieties of maize and certain green varieties of barley a strong blue coloration is present. In the case of pearl millet the evidence is conflicting. We find in black Mexican sweet corn and certain varieties of pop corn that the color is particularly strong, contrasting markedly with the colorless starchy endosperm and the outer bran coats. Noteworthy is Körnicke and Werner's observation, which we have confirmed, that the coloration is located in the so-called "aleurone grains" and not in the network about them. We also note that the color becomes red with acid chloral hydrate solution and is discharged by sodium hydroxide, the first effect of the reagent being a green coloration due to the yellowing of the walls before the blue color has disappeared.

The term aleurone cells is here retained partly because aleurone grains may be present in the network or, if not, aleurone is a fit synonym for protein, and partly because the peculiar form of the cells and the thickened walls correspond to a type of cells present in many seeds containing typical aleurone grains.

Starch Cells.—Adjoining the aleurone cells the starch cells are smaller and the starch grains are smaller than further inward. Throughout the starchy endosperm the cell walls are usually thin; in oats, however, they are swollen in the outer portion of the kernel and in chess they are swollen in all parts. As a rule, the form of the starch grains is much alike in members of the same group, but there are exceptions.

Rye, wheat, and barley have two kinds of grains: (1) large lenticular (up to over 50 μ in rye, somewhat less than 50 μ in wheat, and markedly less in barley) with indistinct rings and hilum and showing faint crosses with polarized light; and (2) small rounded or angular grains. In the chaffy wheats the large grains are slightly smaller than in common wheat.

Maize (excepting sweet and waxy varieties), sorghums, teosinte, and Job's tears have also two kinds of starch grains, quite different, however, from those of the last group. In the horny endosperm they

[1] Handbuch des Getreidebaues. Berlin, 1885.

[2] Landw. Vers.-Stat. 1889, **36**, 337.

are polygonal, cemented together by protein matter but not in rounded or oval aggregates; in the floury endosperm they are rounded. Both forms reach 20 to 30 μ, have distinct hilums, and give brilliant crosses with polarized light. Sweet corn, in addition to soluble carbohydrate, has curious starch grains occurring singly or in aggregates. Waxy maize contains grains of a carbohydrate staining red-brown or purple with iodine.

Common, barnyard, German, and pearl millets and the foxtails have starch grains similar to the maize type but smaller—up to 20 μ. Coracan starch is similar, but grouping in aggregates is not uncommon. Chess has elliptical starch grains up to 20 μ with elliptical hilums.

Other cereals (oats, rice, wild rice, teff, canary seed, manna grass, darnel) have small individual starch grains (less than 10 μ) grouped often in oval aggregates of few or many individuals. They give brilliant polarization crosses but are too small to show much detail of structure.

In all cereal starches the hilum is central.

Protein matter forms the matrix in which the starch grains of horny endosperm are embedded. The film between individual polygonal grains, such as occur in maize, is of necessity thin. Lenticular grains of the wheat type permit a larger amount of protein even in the horny endosperm.

The cell *nucleus* is often seen in aleurone cells without special treatment. In these it is rounded. By means of nuclear stains it may be demonstrated in the starch cells where it appears to be of more irregular form. With our present knowledge, a distinction of the nucleus in different cereals at maturity is impracticable.

In certain of the cereals, notably the sorghums, the protein network enclosing the starch grains often appears granular. Such a granular network is always obtained in the millets and foxtails on treating with very dilute sodium hydroxide. These observations, noted by Harz [1] (who quotes Pfeffer) and afterwards confirmed by Vogl [2] and ourselves, indicate that the protein matter as well as the starch may have definite form in certain cereals. A network of gluten is obtained in wheat by cautiously heating a mount as recommended by Cobb.[3] This treatment does not bring out a granular structure nor does treatment of starch cells of the buckwheat group with sodium hydroxide.

Embryo.—Although the general structure may be seen under the lens in the larger cereals, the microscope must be depended on for details. Starch is absent; fat and proteins, abundant. The nuclei of the cells are

[1] Landwirthschaftliche Samenkunde, Berlin, 1885, p. 1139.
[2] Wichtigsten vegetabilischen Nahrungs- und Genussmittel, Berlin, 1899, p. 154.
[3] Wisconsin Bur. Labor Ind. Statis. 1908, V, 735.

relatively large and may be seen even without nuclear stains. The cells are for the most part polygonal but, in the radicle, as seen in longitudinal section, are more or less rectangular, forming plates, and in the layer of the scutellum adjoining the endosperm they are palisade cells through which the starch of the endosperm after solution by enzymes is transmitted to the plantlet.

The number of secondary radicles varies in the cereals and is best determined by transverse sections. Harz,[1] summarizing the work of Richard, Mirbel, Gärtner, and others, states that in maize, sorghums, and members of the *Panaceæ* (common, pearl, and German millets) there is one secondary radicle; in wheat, rye, and oats, two to four; in barley, four to nine.

The contents of the embryo cells outside of the plantlet proper present much the same appearance as in the aleurone layer.

COMPARATIVE CHEMICAL COMPOSITION.—The following table represents the average composition of the common cereals in the United States on the water- and chaff-free basis.

	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%
Dent maize	11.5	5.6	78.6	2.6	1.7
Sweet maize	12.8	8.8	73.2	3.1	2.1
Brown rice	9.8	2.0	85.8	1.1	1.3
Oats	15.9	7.7	73.2	1.0	2.2
Wheat	13.3	2.3	80.4	2.0	2.0
Rye	12.0	1.9	82.1	1.9	2.1
Naked barley	13.5	2.5	80.3	1.6	2.1

A glance shows that rice with about 86 per cent of starch is preeminently a starch seed, and the others, owing to higher protein and fat content, are somewhat less starchy. Sweet maize and oats represent the first link in the chain leading to true oil seeds. By selection, the starch may be still further reduced, but not to such a degree as to remove any member from the starch seed class.

The groups are here discussed in the same order as in the chapters on the individual cereals.

Proteins.—Overlooking small amounts of proteose and coagulum determined by Osborne, also acid amides, amino acids, and peptides determined by Jodidi et al., the proteins consist of (1) *albumin* (water

[1] Loc. cit., p. 1138.

soluble), (2) *globulin* (brine soluble), (3) *prolamine* or gliadin (alcohol soluble), and (4) *glutelin* (alkali soluble). The amount of albumin is small and of globulin not large; hence, these may also be dismissed from consideration in this place.

Characteristic of the group are the *prolamines* (gliadins), which are represented in all the common cereals, although only in small quantity in rice. Osborne states [1] that prolamines have not been found in any other family of plants. Whether seeds of the *Cyperaceæ* and other families related to the *Gramineæ* have been examined does not appear. Maize contains the largest amount of prolamine, over half of the protein being zein. Sorghum and teosinte, close relatives of maize, contain similar prolamines. Over one-third of the protein of wheat is gliadin, a prolamine, that occurs also in rye and quite probably in barley, but scarcely more than one-tenth of the protein of rice and oats belongs in this group.

Glutelin, a protein group insoluble in water, brine, or alcohol, but soluble in dilute alkali, ranks next to prolamine in point of amount. In maize, a glutelin is somewhat less abundant than zein; in wheat, glutenin (a glutelin) is more abundant than gliadin, whereas in rice and oats glutelins form the bulk of the protein matter.

Figures for amino acids of the proteins and for the nitrogen distribution in the proteins and the grains are given under appropriate heads.

Fat (Oil).—The fat is located almost entirely in the embryo—indeed, it is only by hand separation that the endosperm and bran may be obtained without suspicion that they have taken up oil squeezed out of the germ by machinery. Although the results are somewhat fragmentary, enough has been done to show that there is little difference in the values or the composition of the oil from the different cereals. The general range of the saponification number is from 180 to 194 and the iodine number from 100 to 125. *Oleic* and *linolic acids* together constitute 70 to 80 per cent of the fatty acids, the former being in larger amount in maize and rice, the latter in barley. The remaining acids are *palmitic*, *stearic*, and *linolenic*. The oils are accordingly of the semi-drying class. The unsaponifiable matter of the oils has been shown by Anderson et al. to consist in large amount of *sitosterol* and (or) its isomers and *dihydrositosterol*.

Carbohydrates.—In addition to *starch*, which makes up nine-tenths or more of the nitrogen-free extract, *sucrose* is present in wheat, maize, and doubtless in all the cereals. *Raffinose* occurs in small amount in some or all of the cereals. *Dextrins* and other soluble carbohydrates are stated to occur in members of the group. A soluble carbohydrate is a

[1] Vegetable Proteins, New York, 1912, p. 80.

characteristic of mature sweet maize. *Pentosans* are associated with cellulose and lignin in the bran tissues.

Phosphorus-Organic Compounds.—Maize contains about 0.25 per cent of *lecithin*, and wheat about twice as much, but these amounts represent but a small part of the phosphorus of the kernel. The phosphorus compounds consist in large part of *phytin*, which reaches or exceeds 1 per cent of the kernel.

Enzymes.—Of the enzymes only *diastase*, which forms during sprouting, need here be mentioned. It is distinctly an enzyme of starch seeds essential for conversion of reserve starch into soluble carbohydrates during germination.

Mineral Constituents.—The predominating mineral salts of the naked cereals are *potassium* and *magnesium phosphates*, the amount of the former being about double that of the latter. The magnesia is largely in the bran coats and germ, hence the ash of wheat flour contains about as much lime as magnesia. The chaff is rich in *silica*. *Soda*, *sulphur dioxide*, and *chlorine* occur in variable amounts. Carbon dioxide is absent, hence the ash has practically no alkalinity. Recent work has established the presence of determinable amounts of iron, aluminum, manganese, copper, and zinc, also traces of arsenic.

Respiration of cereal grains, with consequent loss of carbon dioxide, appears to take place throughout ripening and also after harvesting. McGinnis and Taylor [1] found that during the ripening of wheat, barley, and oats the loss was greatest when the grain contained about 40 per cent of water and before drying set in. Loss of carbon dioxide naturally caused a corresponding increase of protein, but other factors contribute to increase the protein, especially in the formation of glutinous kernels.

DENT MAIZE OR INDIAN CORN

Zea Mays L. var. *americana* Mill. = *Z. Mays* L. var. *dentiformis* Körn. = *Z. indentata* Sturt.

Fr. Maïs. Sp. Maiz. It. Miglio Indiano. Ger. Mais.

Although maize or Indian corn is recognized as a plant of American origin, it is uncertain whether or not it is a natural species or, as some botanists believe, a derivative of teosinte (*Euchlæna mexicana* Schrad.); Weatherwax,[2] however, has reached the conclusion that both maize and teosinte are species descended from a common ancestor. Various varietal

[1] J. Agr. Res. 1923, **24**, 1041.

[2] Bul. Torrey Bot. Club. 1918, **45**, 309.

names have been assigned to the different groups by both European and American authors, resulting in much confusion.

Beach, in Bailey's Cyclopedia of Horticulture, gives preference to Sturtevant's classification in seven "agricultural species" as follows: Z. *indentata* (dent), *indurata* (flint), *everta* (pop), *amylacea* (soft), *saccharata* (sweet), *amylea-saccharata* (soft-sweet), and *tunicata* (pod).

All these names would be appropriate as convenient varietal or group (not specific) names, were it not that satisfactory names had previously been adopted for dent, flint, sweet, and pod varieties, or were a definite soft-sweet group tenable, which, as noted by Kempton, appears not to be the case.

Not only is maize in the collective sense the most important American cereal but the acreage as well as the money value of the crop exceed those of any other crop—indeed, this statement doubtless applies to dent maize alone, as it is this variety that is grown in the great corn-producing states of the Middle West. The national prestige of this giant grass is voiced in the saying "Corn is King."

Only a small fraction of the enormous American crop is consumed by human beings, although in some states, notably in the South, maize ranks with wheat as a bread cereal. In most of the country, particularly the parts with the densest population, maize in any form is a human food of secondary importance. By far the greater part of the crop is consumed by animals on the farm where it is produced, and a considerable part of what remains is consumed by animals in regions into which the corn or its products is shipped. Before the advent of prohibition, enormous quantities were used in the brewing and distilling industries. No other product is used in the United States to any considerable extent for starch or glucose manufacture.

MACROSCOPIC STRUCTURE.—Dent maize is characterized by the tooth-like form of the kernel and the indentation at the top, hence the name "dent" has double significance. There are white, yellow, and red varieties. Variegated and blue kernels are less common. By crossing, the same ear may have kernels of a variety of colors. As may be seen by stripping the kernels, the color of yellow varieties is located in both the pericarp and the horny endosperm; of red varieties, only in the pericarp; and of blue varieties, as noted below, only in the contents of the aleurone cells, although the horny endosperm appears blue until the aleurone layer is cut away. White kernels become yellow on soaking in 1 per cent sodium hydroxide; red kernels as well as red chaff elements become green.

The kernels, each in a chaffy cup, are arranged on the cob in double rows, separated during the earlier stages of development by marked

grooves which disappear when the kernels reach their full size. Being in double rows, the total number of rows must be an even number.

Cob (Figs. 39 and 40).—Each double row of kernels is borne on a woody longitudinal strip, each strip separated from its neighbor by a thin partition of soft tissues, the arrangement being like that of the staves of a barrel. Within the *woody zone* thus formed is a narrower zone containing *fibro-vascular* bundles (*fv*), running longitudinally through the cob, from which branches run out through the woody zone to each chaffy cup with its kernel, and within the bundle zone is a central core of *pith* (*m*).

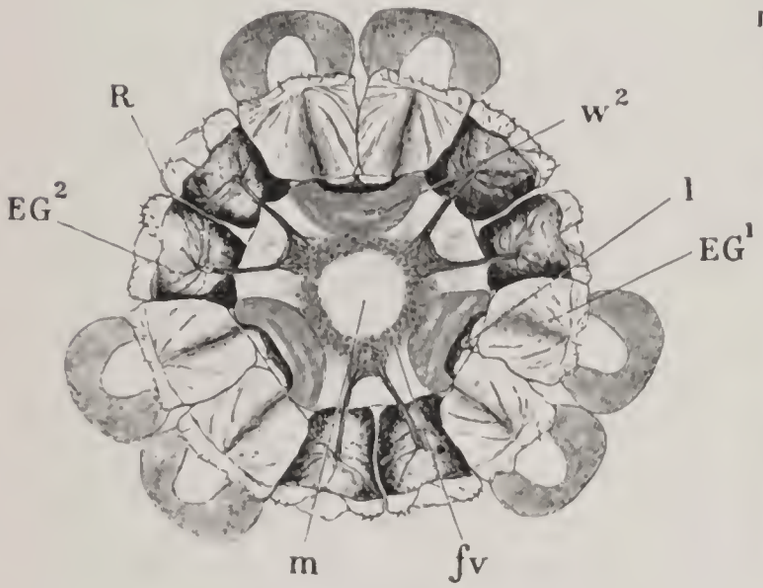


Fig. 39.

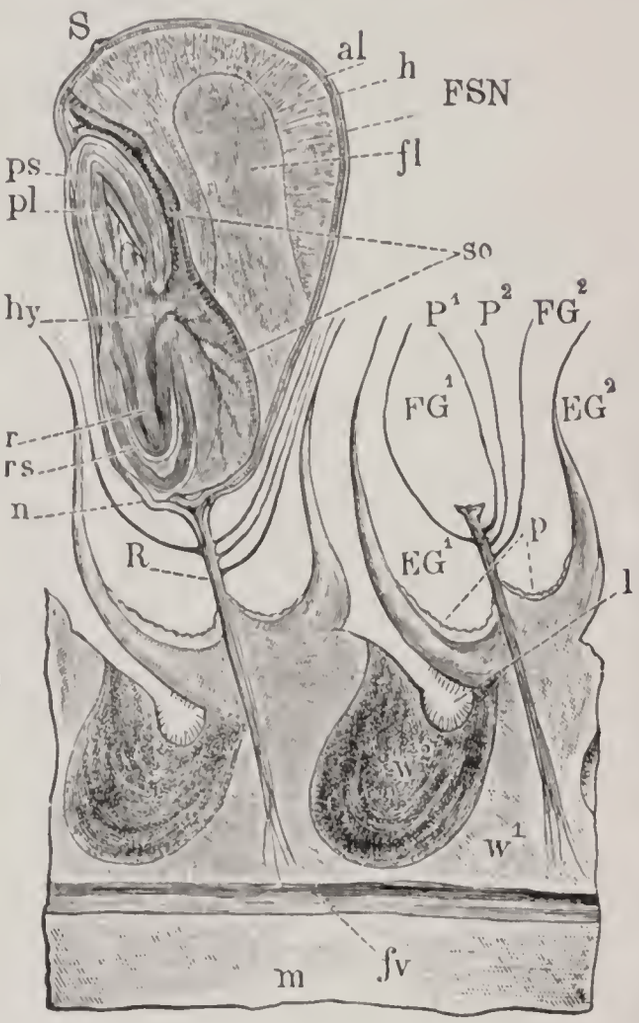


Fig. 40.

Fig. 39.—Maize. Ear in cross section looking toward base. ×1. Reference letters as in Fig. 40. (A.L.W.)

Fig. 40.—Maize. Ear in radial section. Cob: w^1 softer and w^2 harder tissues of woody zone; *fv* bundle zone; *m* pith; *R* rachilla; EG^1 lower empty glume; EG^2 upper empty glume; FC^1 flowering glume and P^1 palet of perfect flower; FG^2 flowering glume and P^2 palet of rudimentary flower; *l* depression in woody zone; *p* spongy lining of empty glumes. Kernel: *FSN* pericarp, spermoderm, and perisperm; endosperm with *al* aleurone cells, *h* horny and *fl* floury part; embryo with *pl* plumule, *ps* plumule sheath, *hy* hypocotyl, *r* radicle, *rs* radicle sheath, and *sc* scutellum; *S* remains of stigma; *n* micropyle. ×4. (A.L.W.)

On the surface of the cob, separating each pair of kernels in a double row from its neighbor in the row, are transverse depressions (*l*) clothed with hairs. Beneath these depressions the tissues (w^2) of the woody zone are denser and darker colored than in other parts (w^1).

The chaffy cups are formed by two *empty glumes* (EG^1, EG^2), the *flowering glume* (FG^1) and *palet* (P^1) of the fertile flower and the *flowering glume* (FG^2) and *palet* (P^2) of a rudimentary flower. Of these, the empty glumes are thick and horny, except on the tip; the flowering glumes and palets are thin and papery. Hairs, evident under a lens, occur on the bases of the empty glumes and on the thin tips. The inner basal portions of the empty glumes are lined with a soft tissue (*p*).

Kernel (Figs. 39 and 40).—The general structure is quite evident to the naked eye because of the large size of the grain and its embryo. On the more or less flattened ventral side is a conspicuous central depression, about one-third the breadth of the kernel, extending nearly to the apex. Beneath this is located the large embryo forming, according to Hopkins, Smith, and East,[1] 9.59 per cent of a low-protein (9.28 per cent) kernel and 11.93 per cent of a high-protein (12.85 per cent) kernel, all calculated to the water-free basis. The dorsal side is smooth and without a groove such as occurs on members of the wheat group, oats, and many other grass fruits.

A longitudinal section carefully cut with a penknife shows within the bran coats (*FSN*), consisting chiefly of *pericarp* and *aleurone cells* (*al*), a mass of *horny endosperm* (*h*), a central core of *floury endosperm* (*fl*), and the *embryo*. The remains of the *stigma* (*S*) form a small hump on the top which in some varieties of the species is continued into a horn. In the embryo may be seen the shield-like *scutellum* (*sc*), with its veining of procambium bundles, on one side adjoining the endosperm, on the other attached in the center to the *hypocotyl* or stem of the plantlet (*hy*), the *plumule* or roll of leaves (*pl*) above the hypocotyl, encased in the *plumule sheath* (*ps*), and the *radicle* or rootlet (*r*), below the hypocotyl, encased in the *root sheath* (*rs*). As is not the case with wheat, the botton lobe of the scutellum is much larger than the top lobe. Also there is no evident ligule of the hypocotyl. The *micropyle* (*n*) or opening through which fertilization took place is at the bottom of the embryo.

MICROSCOPIC STRUCTURE.—No well-marked distinctions in microscopic structure between dent and flint varieties of maize have yet been brought out. Pop corn also has practically the same structure.

Rachis (Spindle of Cob).—The structure of the different parts varies somewhat according to the position. Proceeding from the bottom of the depression, shown at *l* in Figs. 39 and 40, through the cob to the pith, the elements seen in radial section (Fig. 41) are (1) *epiderm* of small, thin-walled cells with unicellular, taper-pointed *hairs* and jointed, blunt-pointed *hairs*; (2) *sclerenchyma zone*, the cells ranging from elongated forms, arranged parallel to the surface, in the outer layers to large iso-

[1] Illinois Agr. Exp. Sta. 1903, Bul. 87.

diametric forms in the inner layers; (3) *bundle zone* with annular, spiral, sclariform, and pitted vessels; and (4) *pith* of round-celled parenchyma with thin walls and conspicuous intercellular spaces.

The cells of the *epiderm* in surface view (Fig. 42, *ep*), are small, more or less isodiametric, with deeply sinuous walls. The *unicellular hairs*

Fig. 41.

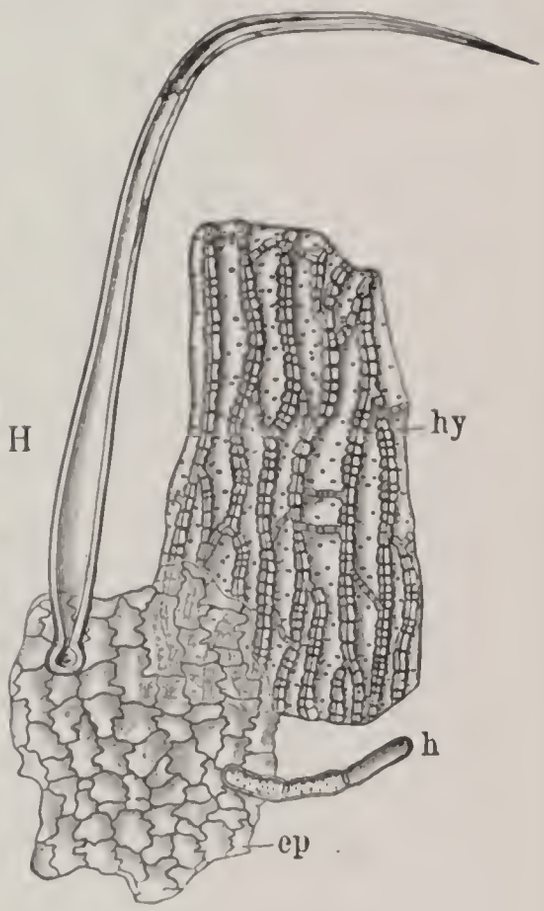


Fig. 42.

Fig. 43.

Fig. 41.—Maize. Cob in radial section through depression (*l*, Figs. 39 and 40) showing epiderm with hairs, elongated and isodiametric sclerenchyma cells, fibro-vascular bundle, and parenchyma of pith. ×32. (A.L.W.)

Fig. 42.—Maize. Cob in surface view of depression (*l*, Figs. 39 and 40). *ep* epiderm with *H* unicellular hair and *h* blunt three-celled hair; *hy* hypoderm. ×160. (A.L.W.)

Fig. 43.—Maize. Rachis (cob) in cross section through elongated sclerenchyma of woody zone. ×160. (A.L.W.)

(*H*) are small and globular at the base, broadening above into a wide lumen; the *jointed hairs* (*h*) have two or more joints and thin, often beaded, walls.

The elongated cells of the woody zone in cross section show branching canals and concentric rings, appearing like stone cells (Fig. 43). In

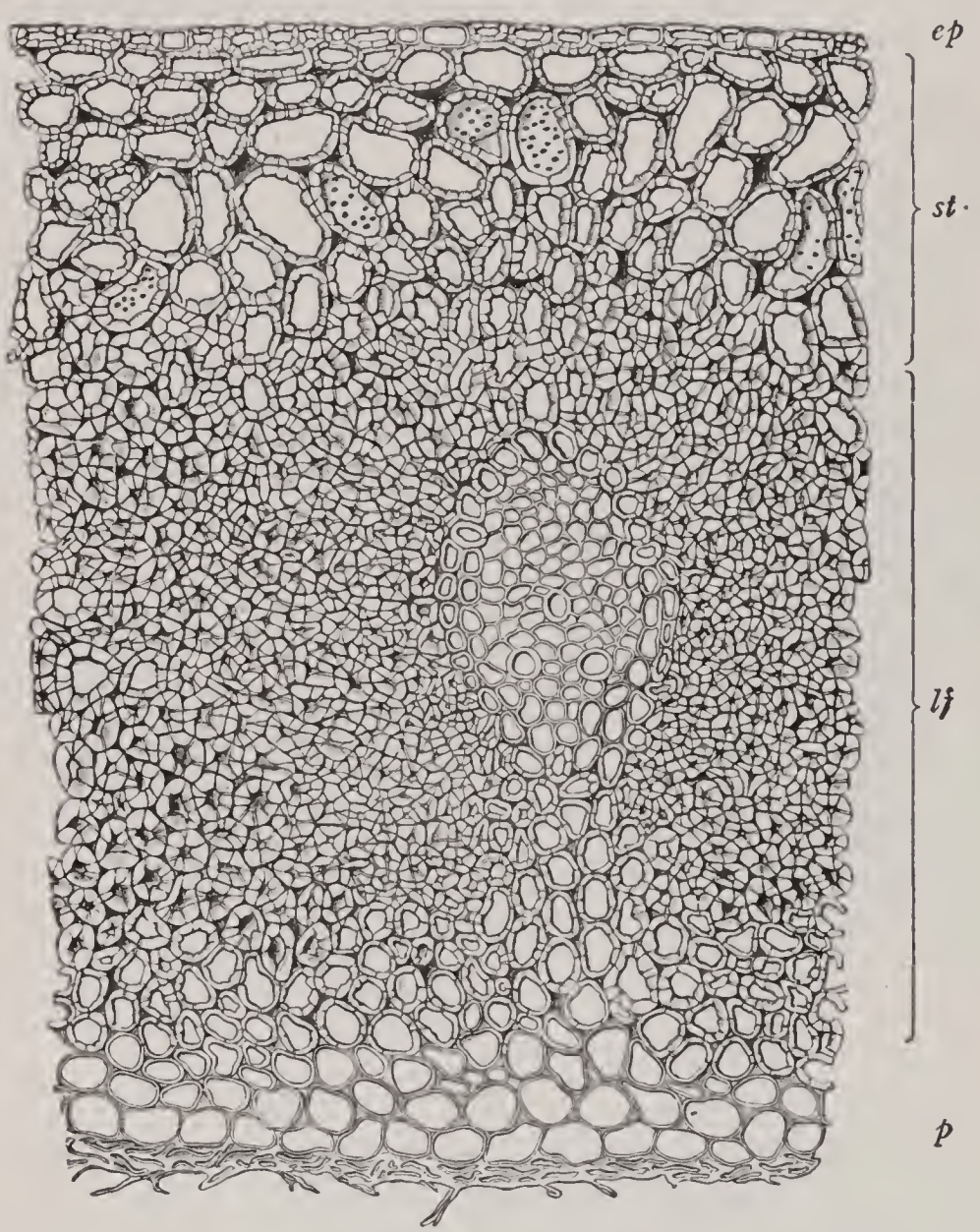


FIG. 44.—Maize. Upper empty glume in cross section. *ep* epiderm with thick-walled porous and thinner-walled non-porous cells; *st* isodiametric cells; *lf* longitudinally elongated sclerenchyma cells and fibro-vascular bundle; *p* parenchyma with compressed inner layers. ×160. (A.L.W.)

surface view (Fig. 42, *hy*) the cells immediately underlying the epiderm are somewhat like the hypodermal cells of wheat.

The epiderm between the depression and the base of the top empty glume is quite different from that in the depression, being practically the same as the outer epiderm of the empty glumes.

Empty Glumes.—The bulk of the tissue is horny but at the end is papery. A cross section through a vein with its bundle is shown in

Fig. 44. The tissues are (1) *outer epiderm* (*ep*) of characteristic porous and non-porous cells, (2) outer zone of *isodiametric sclerenchyma* cells (*st*) with large lumens, (3) middle zone (*lf*) of *sclerenchyma fibers* with thick walls and small lumen, through which runs the *fibro-vascular bundle* with conspicuous vessels, (4) *parenchyma* (*p*), and (5) *compressed parenchyma.*

The *outer epiderm* in surface view (Fig. 45) is strikingly characteristic. The porous cells are thick-walled, elongated or isodiametric; the non-

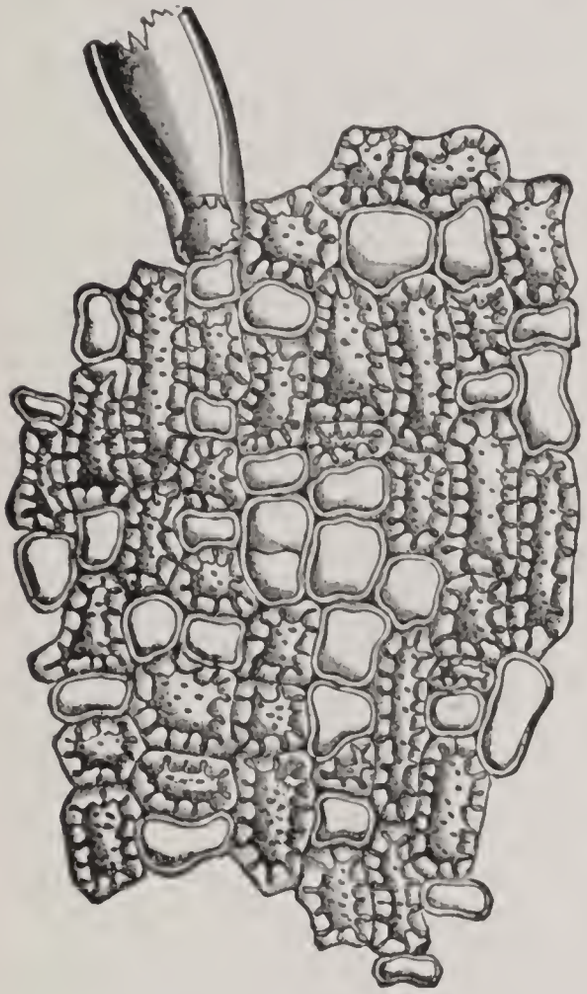


Fig. 45.

Fig. 46.

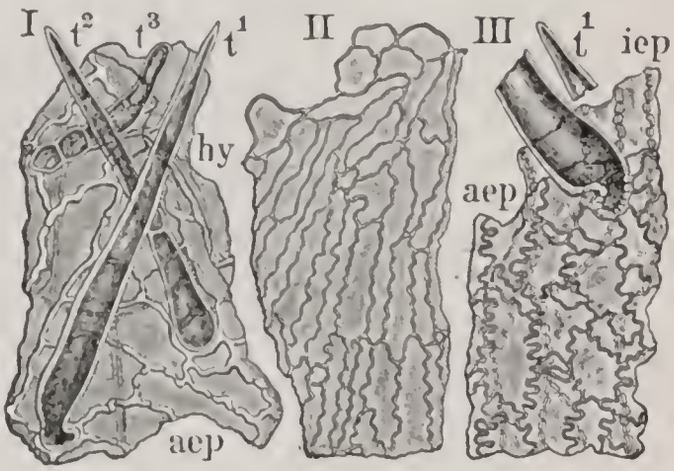


Fig. 47.

Fig. 45.—Maize. Empty glume in surface view showing outer epiderm with porous and non-porous cells and base of hair. ×300. (A.L.W.)

Fig. 46.—Maize. Hairs from different parts of cob. ×160. (A.L.W.)

Fig. 47.—Maize. I tissues from base and II tissues from tip of flowering glume. III tissues from near edge of membranous tip of thick empty glume. *aep* outer epiderm with t^1, t^2, and t^3 one-, two-, and three-celled hairs respectively; *hy* hypoderm; *iep* inner epiderm. ×160. (A.L.W.)

porous cells are thinner-walled, often elliptical or crescent-shaped, and occur singly, in pairs, or in groups. Their analogy to the round cells and twin cells of oat and barley chaff is often evident. *Hairs* occur on the epiderm in parts. Those on the main part of the glume are often long, whereas at the base, short hairs, shown at the extreme right in Fig. 46, are present.

At the ends of the empty glumes the papery tissue lacks the scler-

enchyma and parenchyma layers. The outer epiderm (Fig. 47, III) is made up of cells with thin, deeply sinuous walls and hairs, the sinuosities disappearing at the very margin.

An *inner epiderm* of elongated straight-walled cells is present except at the very edge.

Flowering Glumes and Palets.—These have practically the same structure as the papery ends of the empty glumes, but hairs are few or lacking except at the base. At the extreme end the walls become straight and the elongated form changes to isodiametric (Fig. 47, II). At the base the tissues are more robust, and hairs of various types are present (Fig. 47, I).

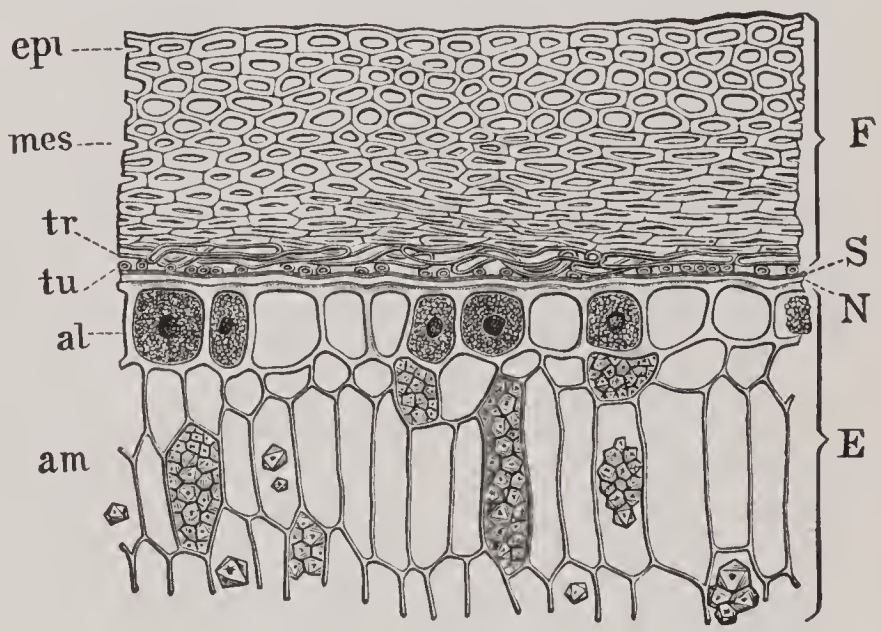


Fig. 48.—Maize. Kernel in cross section through dorsal side. *F* pericarp: *epi* epicarp, *mes* hypoderm (mesocarp), *tr* cross cells, *tu* tube cells (endocarp). *S* spermoderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *am* starch cells. ×160. (A.L.W.)

Pericarp (Fig. 48, *F*; Fig. 49).—Soaking for some hours in water or boiling for a few minutes with 1 per cent sodium hydroxide loosens the outer from the inner bran layers, the separation being through the cross cells.

The tissues on the central dorsal side of the grain are (1) *epicarp* (*epi*, *epi*[1]) of elongated, distinctly porous cells without hairs; (2) *hypoderm* (*mes*, *hy*) of twelve cell layers, more or less, similar to the epicarp: (3) *cross cells* (*tr*) forming a spongy parenchyma; and (4) numerous narrow *tube cells* (*tu*).

The *epicarp* cells at the apex (*epi*[2]) are much smaller than those on the body of the grain but otherwise similar; at the base (*epi*[3]) they are somewhat narrower, much shorter, and less distinctly beaded.

The *hypoderm*, including mesocarp, forms the bulk of the pericarp. The cells being closely adherent one to the other, their structure is much obscured in surface view. In cross sections the lumens in the outer hypodermal layers are more conspicuous than in the inner.

Both the *cross cells* and the *tube cells* of maize are distinctly different from those of the wheat group but are more like those of oats, rice, and the sorghums. Although it is difficult to determine whether the cross cells are in one, two, or more layers, the anastomosing arms indicate that they are in two layers at least.

Spermoderm (Figs. 48 and 49, *S*).—After the pericarp layers have been stripped off as indicated above, further stripping will separate the spermoderm and aleurone cells. When mounted in chlorzinc iodine solution the spermoderm is seen to consist of a cuticular skin staining yellow, but no cellular structure is ordinarily evident. In cross section, similar treatment differentiates the spermoderm as a narrow yellow band.

Perisperm (Fig. 48, *N*).—This also shows no cellular structure either in cross section or surface view, although in cross section it forms a narrow colorless band. Authors who report finding cellular structure in either the spermoderm or perisperm may have mistaken, for one or the other of these, striations due to tube cells or the network formed by

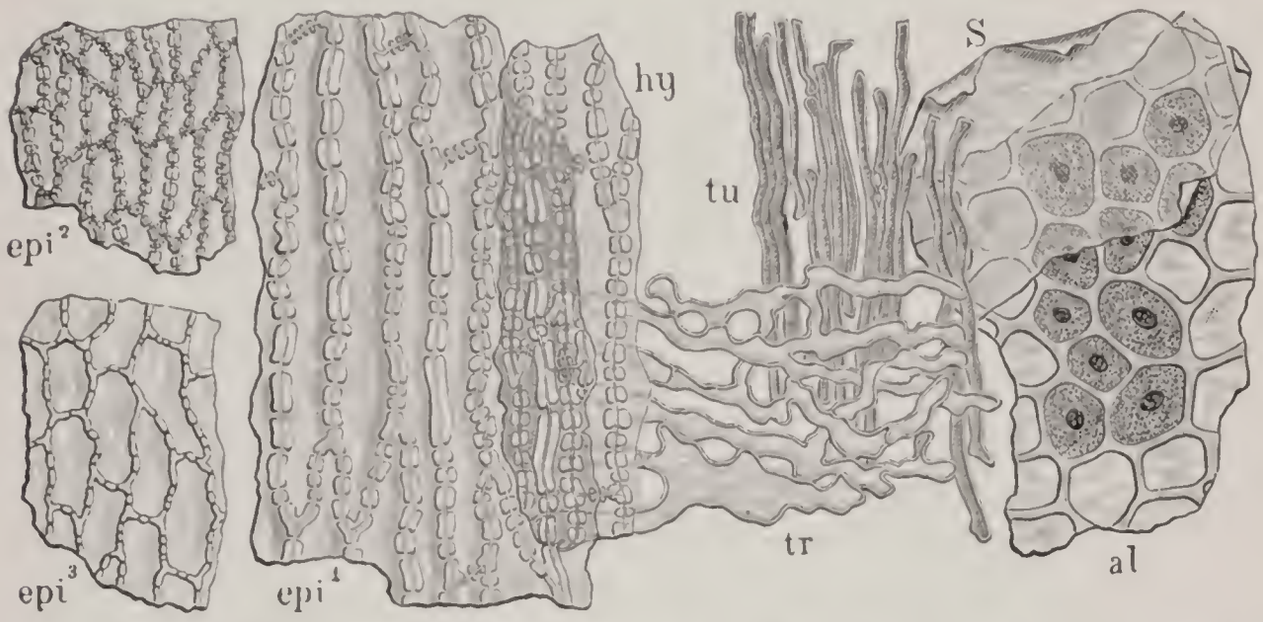


Fig. 49.—Maize. Bran coats in surface view. *epi*³ epicarp at base; *epi*² epicarp at apex. Layers on dorsal side: *epi*¹ epicarp, *hy* hypoderm, *tr* cross cells, *tu* tube cells, *S* spermoderm, *al* aleurone cells. ×160. (A.L.W.)

adherence of the outer walls and part of the radial walls of the aleurone cells to the united spermoderm and perisperm, both common phenomena.

Endosperm (Fig. 48, *E*).—The *aleurone cells* (Figs. 48 and 49, *al*) are in a single layer. Division into two cells by tangential partitions is rare. Measured in surface preparations they differ little in size from the aleurone cells of rice and oats. Special mention should here be made of the strong blue coloration of the contents of the aleurone cells of blue varieties as seen in cross section, contrasting strikingly with the colorless starchy endosperm and the outer bran coats. This statement applies also to blue or blue-black sweet and pop varieties. See preliminary chapter on Cereals.

The *starch cells* in the horny endosperm are closely packed with *starch grains* (Plate II, Fig. 13) cemented together by zein or other protein contents, forming a solid mass. Because of the close packing the form

of the grains is polygonal. Aggregates such as occur in rice and oats are not present. Rounded forms make up the bulk of the loose grains in the floury endosperm. Among the small grains are various forms such as triangular, diamond-shaped, rectangular, sugarloaf-shaped, etc. The size of both polygonal and rounded grains varies up to 30 μ or a trifle more. A large central hilum or a corresponding rift or rosette of rifts is present. With polarized light, bright crosses are formed.

Embryo.—In microscopic structure the embryo is much like wheat embryo, but the cells are larger, particularly in the radicle.

CHIEF STRUCTURAL CHARACTERS.—Cob with woody zone and soft pith; chaff with thick and thin glumes; kernel tooth-shaped, flattened, with dent at top. Endosperm with differing proportions of horny and floury substance; embryo large, beneath depression.

Woody zone of cob with elongated and isodiametric sclerenchyma cells. Empty glumes with thick-walled porous and thin-walled non-porous epidermal cells. Thin glumes and palets with elongated wavy-walled cells. Various parts of cob with pointed unicellular and blunt jointed hairs. Hypoderm of kernel much thicker than in other cereals; cross cells tubular, unlike those of the wheat group but much like those of rice, sorghum, and oats. Spermoderm with no evident cellular structure (distinction from the wheat group). Starch grains polygonal or rounded, up to 30 μ or more, with distinct hilum. Embryo oily.

MICROSCOPY OF MAIZE PRODUCTS.—The following applies to products of both dent and flint maize.

Corn and Cob.—Only one product, an unusual one, known as "cob meal" consists of the ground whole husked ear. Strictly speaking, this is corn and cob meal. The low feeding value of the cobs and the difficulty of grinding them militate against the product. Parts of the cob, particularly hard lumps of the woody zone, and fragments of the thick and papery chaff elements, also fragments of bran, embryo, and lumps of horny endosperm, may be picked out and identified under the microscope.

Whole Kernel Products.—*Corn Meal* ground by mill stones without separation of the bran or embryo, a primitive product, is still esteemed in some sections, particularly in the Southern States. Owing to the presence of the embryo, the meal deteriorates rapidly and is best prepared and consumed locally. Fragments from different parts of the kernel may be picked out and examined, noting the elements referred to under Chief Structural Characters.

Cracked Corn is a coarse product suited for young poultry.

Decorticated Products.—Both raw and cooked products are marketed. The uncooked products, manufactured by modern machinery, differ in the degree of fineness, the order being (1) *hominy* or *corn grits*,

(2) *coarse meal*, (3) *fine meal*, and (4) *corn flour*. The first two consist largely of the horny endosperm whereas the last two contain more of the starchy endosperm with its preponderance of rounded starch grains.

Corn Flakes, consisting essentially of rolled and roasted grits, is a package cereal food highly esteemed in the United States. The starch grains are much distorted.

Puffed Corn is made from large lumps of the endosperm " exploded " by heat as described for puffed wheat.

Lye Hominy or *Hulled Corn* is a product inherited like the cereal itself from the aborigines who used as the decorticating agent wood ashes. Formerly prepared in the household or by local venders, using the primitive process, it is now decorticated by lye on a large scale in canning establishments. The kernels swell during manufacture to considerable size, which phenomenon is associated with the distortion of the starch granules.

Corn Starch.—See Commercial Starch.

Corn Offals.—*Corn Cobs*, being rich in pentosans, have offered a fertile field for technical investigation. Where fuel is scarce and corn plenty they are often burned for their heat. Tobacco pipes, made by hollowing out the center to the woody layer and trimming off the chaff, are well known in the United States. Manufactures of furfural, adhesives, and other cob products, bid fair to reach large proportions.

The addition of ground cobs to wheat bran, a fraud that led one of us[1] to make a systematic study of the cobs, is now infrequent. Among the tissues of the cob unlike those of wheat bran are (1) pointed hairs with lumens several times the thickness of the walls, (2) jointed hairs, (3) sclerenchyma in hard lumps, (4) wavy-walled epidermal cells of the thin chaff, and (5) the two forms of epidermal cells of the thick chaff. The last named may be removed by warming fragments in 1 per cent sodium hydroxide and scraping.

In the preparation of decorticated products, *Corn Bran* is obtained or else a by-product containing the bran. Corn bran has at times been added to wheat bran, to which it is inferior partly because the hypoderm is much thicker and partly because the natural separation through the cross cells tends to leave the aleurone layer with the more starchy products.

Starchy by-products of the manufacture of hominy include *Hominy Feed* and *Starch Feed.*

Gluten Meal, the highly nitrogenous dried residue obtained in the manufacture of glucose, consists of hard, rounded lumps, with such

[1] Oesterr. Chem. Ztg. 1900, **3** N.F., 345; Connecticut Agr. Exp. Sta. Rep. 1900, p. 186.

starch as remains well disorganized. Bran elements are present but not in such amount as in gluten feed.

Germ Cake is the residue from the manufacture of maize oil from the embryo separated by degermination and is ground to form *Germ Oil Meal.* The germ tissues are readily recognized.

CHEMICAL COMPOSITION.—For convenience in comparison, all the varietal groups (dent, flint, pop, soft, and sweet) are treated together in this section.

Maize Cob.—The minimum, maximum, and average results of eighteen early analyses, given in Jenkins and Winton's Compilation[1] follow:

Composition of Maize Cob

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	7.18	1.22	0.08	43.84	18.21	0.68
Max.	24.76	3.73	0.92	66.68	38.26	2.73
Average	**10.68**	**2.37**	**0.52**	**54.89**	**30.13**	**1.41**

Analyses made at the Connecticut Agricultural Experiment Station[2] confirm the early results.

Cellulose, xylan, and *lignin* are the chief substances, irregularly divided between the nitrogen-free extract and fiber.

Hudson and Harding[3] obtained a yield of 12 per cent of crude xylose of high purity from maize cobs and rate this raw material as a better source of the sugar than cottonseed hulls.

By successive treatment of cobs, La Forge and Hudson[4] secured adhesive gum 30, crystalline xylose 5, acetic acid 2.5 to 3, and crystalline glucose 37 per cent. The xylose is about half as sweet as sugar.

Lignin.—Hägglund and Malm[5] claim that pentosans are an integral part of the lignin molecule. Heuser[6] and Phillips[7] present evidence to the contrary.

Phillips, by extraction of cobs with dilute sodium hydroxide, neutralization, and precipitation with hydrochloric acid, prepared lignin

[1] U. S. Dept. Agr., Off. Exp. Sta., 1892, Bul. **11.**
[2] Rep. 1889, pp. 25, 26, 222.
[3] J. Am. Chem. Soc. 1918, **40,** 1601.
[4] J. Ind. Eng. Chem. 1918, **10,** 925.
[5] Cellulosechem. 1923, **4,** 73, 84.
[6] Ibid. 1923, **4,** 77.
[7] J. Am. Chem. Soc. 1927, **49,** 2037.

amounting to 3.49 per cent of the cobs, corresponding to the formula $C_{40}H_{46}O_{16}$, which is in reasonable agreement with the formulas of lignin from rye straw, $C_{40}H_{44}O_{15}$, given by Beckmann, Liesche, and Lehmann,[1] and from flax shoves, $C_{45}H_{48}O_{16}$, given by Powell and Whittaker.[2]

Maize Kernel and Mill Products.—All the analyses summarized in the following table are from Jenkins and Winton's Compilation[3] except 18 of samples exhibited at the World's Fair at Chicago in 1893[4] and 12 analyzed in 1906 and reported by Chamberlain.[5]

Generalizations from tables of composition like the one below should

Composition of Maize

	Samples	Water	Protein (N×6.25)	Fat	N-f.ext.	Fiber	Ash
		%	%	%	%	%	%
Dent varieties 1892:	86						
Min.		6.22	7.53	3.10	65.40	0.88	1.04
Max.		19.42	12.78	7.49	75.73	4.81	2.64
Average		10.56	10.25	5.02	70.40	2.24	1.53
Flint varieties 1892:	68						
Min.		4.53	7.00	3.40	64.95	0.67	1.03
Max.		19.60	13.65	7.13	76.74	2.88	1.92
Average		11.31	10.52	4.99	70.09	1.65	1.44
Dents and flints:							
World's Fair 1893	18						
Average		10.93	9.88	4.17	71.95	1.71	1.36
Chamberlain 1906	12						
Average		13.06	8.61	3.84	71.25	1.93	1.31
Sweet varieties:	26						
Min.		5.98	9.45	3.79	61.78	1.46	1.42
Max.		10.86	15.31	11.90	72.35	5.24	2.35
Average		8.82	11.62	8.13	66.72	2.79	1.92
Pop varieties:	4						
Min.		8.61	9.69	4.18	68.38	1.16	1.24
Max.		12.60	13.13	5.98	71.09	2.34	1.74
Average		10.71	11.22	5.18	69.66	1.76	1.47
Soft varieties:	5						
Min.		6.09	8.82	5.00	65.97	1.28	1.41
Max.		14.08	14.56	5.74	75.50	3.25	1.85
Average		9.26	11.41	5.47	70.29	2.00	1.57

[1] Z. angew. Chem. 1921, **34**, 285.

[2] J. Chem. Soc. 1924, **125**, 357; 1925, **127**, 132.

[3] Loc. cit.

[4] U. S. Dept. Agr., Bur. Chem., 1895, Bul. **45**.

[5] Ibid. 1909, Bul. **120**.

be made with caution, as it is impossible to secure samples accurately representative of the whole country, all years, and all varieties, especially as the same variety varies so greatly through natural causes as well as breeding. Hence it is not justifiable to conclude from the averages that dents and flints are practically identical in composition, or that field corn (dent and flints) has degenerated in protein content from before 1892 to 1906, although such may appear on the surface to be the case. It may, however, be safely stated *first*, that maize (including all varieties) has a higher fat content, owing to the larger embryo, than any other cereal, and *second*, that sweet corn has a higher fat content than any other varietal group, even when allowing for an increase due to breeding.

Relation of Ripeness to Composition.—An extensive series of analyses of immature maize ("soft corn") as compared with mature maize has been made by Spitzer, Carr, and Epple at the Purdue Experiment Station.[1] Three grades were chosen: (1) very immature, incapable of germinating, (2) more mature, capable of germinating, and (3) intermediate. A summary of the first two and mature maize follows:

AVERAGE COMPOSITION OF NORMAL AND IMMATURE MAIZE (SPITZER, CARR, AND EPPLE)

	Normal	Immature	Very immature
Results in percentage of kernel:			
Water	10.50	6.21	8.06
Protein	10.10	10.60	9.92
Fat	5.00	4.28	2.67
Water-soluble starch and dextrin	3.38	2.17	2.40
Normal starch (diastase)	42.50	47.65	45.77
Total starch (acid hydrolysis)	71.95	75.18	
Pentosans, etc. (difference)	24.87	.....	24.87
Fiber	2.00	2.36	4.38
Ash	1.50	1.56	1.95
Results in percentage of total nitrogen:			
Total melanin nitrogen	9.78	8.00	9.68
Ammonia nitrogen	12.53	14.23	13.41
Monoamino acid nitrogen	63.43	69.41	63.16
Diamino acid nitrogen	15.86	10.58	11.26
Amide nitrogen	.....	5.27	15.08
Results in percentage of total protein:			
Glutelins	31.00	42.45	40.63
Zein	41.00	29.41	22.14
Globulins, etc.	22.00	21.61	23.04

[1] J. Am. Chem. Soc. 1919, **41**, 1212.

The authors note that the normal starch, nitrogen-free extract, and amide nitrogen appear to be higher in immature than mature maize. Moldy maize contains a large amount of nitrogen in amide form. The formation of protein and carbohydrates apparently proceeds steadily during growth whereas fat is formed last. Glutelin, the most abundant protein of maize, seems to occur in smaller amount in immature than mature maize. Amide nitrogen and acidity may serve as an index of grading. The acidity, given only for medium immature kernels, ranged from 15.2 to 41.8.

Breeding as Affecting Composition.—In 1896, Hopkins and his associates at the Illinois Agricultural Experiment Station, realizing the different purposes for which maize is used and the desirability of increasing or decreasing the content of certain constituents to meet special requirements, undertook to breed maize with high and low protein content (and correspondingly low and high starch content) and high and low fat content. Starting with one variety ("Illinois"), Hopkins, Smith, and East,[1] in seven generations by selection based on chemical analysis of part of the kernels of each ear, obtained strains with high and low protein and high and low oil contents having the following composition:

	Protein	Fat (oil)	Carbohydrates	Ash
	%	%	%	%
High protein	14.44	4.93	79.06	1.56
Low protein	6.71	4.21	87.71	1.37
High oil	11.31	7.00	80.14	1.55
Low oil	9.98	2.52	86.07	1.44

In 1912, after fifteen years of breeding, Smith [2] states that the variety known as "Burr's White," with 10.92 per cent of protein and 4.70 per cent of fat in 1896, was bred so as to secure strains with a stretch of 7.89 to 13.78 per cent of protein and other strains with a stretch of 2.05 to 7.51 per cent of fat.

Distribution of Constituents in Kernel.—Vorhees [3] dissected maize kernels and obtained separately endosperm, embryo, and hulls. Analyses of these same parts yielded, respectively, the following results, calculated to the water-free basis: protein 12.15, 19.54, 6.52; fat 1.53, 26.65, 1.57; nitrogen-free extract 84.99, 41.20, 74.42; fiber 0.65, 2.59, 16.24; ash 0.68, 10.02, 1.25 per cent.

[1] Illinois Agr. Exp. Sta., 1903, Bul. **87.**

[2] Eighth Int. Cong. Appl. Chem. 1912, **13,** 261.

[3] New Jersey Agr. Exp. Sta. 1894, Bul. **105.**

DISTRIBUTION OF PARTS AND CHEMICAL CONSTITUENTS IN THE MAIZE KERNEL
(HOPKINS, SMITH, AND EAST)

(Results in percentages of the dry whole grain)

	Physical distribution	Protein (N×6.25)	Fat (oil)	Carbohydrates	Ash
	%	%	%	%	%
Low-protein ear:					
Tip cap	1.20	0.09	0.01	1.09	0.01
Hull	5.47	0.27	0.05	5.10	0.04
Horny gluten *	11.61	2.23	0.46	8.81	0.11
Horny starch †	37.15	3.02	0.06	34.01	0.07
Crown starch	21.26	1.53	0.04	19.62	0.07
Tip starch	13.71	0.84	0.04	12.79	0.04
Embryo (germ)	9.59	1.91	3.50	3.17	1.01
Total	99.99	9.89	4.16	84.59	1.35
Whole grain	.....	9.28	4.20	85.11	1.41
Medium-protein ear:					
Tip cap	1.46	0.13	0.03	1.28	0.02
Hull	5.93	0.23	0.05	5.60	0.05
Horny gluten *	8.51	1.89	0.59	5.88	0.15
Horny starch †	47.08	4.80	0.11	42.05	0.11
Crown starch	17.01	1.35	0.03	15.59	0.04
Tip starch	8.48	0.65	0.03	7.77	0.03
Embryo (germ)	11.53	2.28	4.02	4.09	1.14
Total	100.00	11.33	4.86	82.26	1.54
Whole grain	.....	10.95	4.33	83.17	1.55
High-protein ear:					
Tip cap	1.62	0.08	0.03	1.48	0.03
Hull	6.09	0.23	0.05	5.74	0.07
Horny gluten *	13.32	3.27	0.61	9.20	0.23
Horny starch †	44.89	4.93	0.10	39.76	0.09
Crown starch	13.88	1.20	0.07	12.56	0.05
Tip starch	8.28	0.60	0.11	7.51	0.05
Embryo (germ)	11.93	2.33	4.02	4.38	1.19
Total	100.01	12.64	4.99	80.63	1.71
Whole grain	.....	12.85	5.36	80.12	1.67

* Outer endosperm including aleurone cells.
† Inner horny endosperm.

Hopkins, Smith, and East [1] designate the parts of the kernel as (1) *tip cap*, the loose basal tissues; (2) *hull*, the thin outer bran coat;

[1] Loc. cit.

(3) *horny gluten*, the outer horny or glassy part including the aleurone layer containing starch as well as protein; (4) *horny starch*, the inner horny or glassy tissue containing protein as well as starch; (5) *starchy matter* arbitrarily divided into *crown starch* (in the broad end) and *tip starch* (in the narrow basal end); and (6) *germ* (embryo).

After soaking for 15 to 20 minutes, these parts were separated mechanically—the tip cap by cutting under one edge and pulling, the hull by stripping, the horny gluten by shaving, the tip and crown starch by scraping, and the germ by careful dissection. In the process about 20 per cent of "mixed waste," derived from horny gluten, horny starch, and crown and tip starch, accumulated, and like the other parts was weighed and separately analyzed.

From the percentages of these parts and the analysis of each were derived, by calculation, tables in which the mixed waste and its chemical constituents were added in suitable proportion to the parts from which it was derived, the errors of this procedure being too slight to affect the general conclusions seriously. One of these tables, showing the proportion of the several parts thus corrected in the whole grain and the chemical constituents in each part, expressed in percentage of the dry whole grain, is here reproduced. From it may be derived the composition of each part in percentage of the part by multiplying each chemical constituent by 100 and dividing by the percentage of that part in the whole grain.

A glance at the foregoing table shows that the "tip cap" and "hulls" contain insignificant amounts of food constituents, that the fat and ash are largely located in the embryo and that the protein and carbohydrates are largely distributed among "horny gluten," "horny starch," "crown starch," and "tip starch." A low carbohydrate content and in this particular case a somewhat higher embryo and fat content are correlated with a high protein content. The authors state, however, that an increase in protein does not necessarily mean an increase in fat—in fact, in some cases there is a decrease.

The composition of the embryo and of the endosperm and hulls, after the removal of the embryo, of representative high- and low-protein and also of high- and low-oil samples illustrates well the wide difference in the percentages of the constituents and certain correlations. The figures tabulated on the following page are the averages of agreeing duplicates.

The endosperm of the high-protein strain contained nearly two and one-half times as much protein as that of the low-protein strain; the embryo of the two strains, however, showed only moderate differences. High protein was associated with low starch, and vice versa.

Composition of Parts of Maize Kernel Bred for High and Low Constituents (Hopkins, Smith, and East)

	Kind of corn	Protein (N×6.25)	Fat (oil)	Carbohydrates (by difference)	Ash
		%	%	%	%
Embryo	low-protein	18.01	34.09	37.73	10.17
	high-protein	21.25	35.50	33.15	10.10
	low-oil	21.71	24.81	40.24	13.24
	high-oil	17.69	41.76	31.77	8.78
Endosperm and hulls	low-protein	5.69	0.87	93.01	0.43
	high-protein	13.80	0.74	85.08	0.38
	low-oil	9.14	0.51	89.90	0.45
	high-oil	10.36	1.15	88.11	0.38

In the case of the high- and low-oil strains it was the embryo that showed striking differences in composition. The very high fat content of the high-oil strain was correlated with very low carbohydrate content but with relatively not so low protein content.

The authors call attention to the preponderance of horny gluten as an index of high protein and a large embryo as an index of high oil, thus enabling the farmer to select his seed without recourse to chemical analysis.

Products of Maize Milling.—The analyses below, reported by Winton, Burnet, and Bornmann,[1] represent a series of products of two roller process mills, one grinding white corn, the other, yellow corn. The meal manufactured in both mills was degerminated and bolted. The meal, flour and grits were analogous to the different grades of wheat flour, exclusive of low grade, obtained in the roller or gradual reduction process. The meal corresponding to the low-grade flour of the wheat mills was run in with the feed.

Corn (Maize) Meal.—Winton, Burnet, and Bornmann [2] distinguish four types of corn meal milled in the United States for human consumption: (1) whole kernel, (2) undegerminated, bolted, (3) degerminated, bolted, and (4) " standard,"a lower grade separated from the last named, corresponding to " clear " wheat flour. The corn may be white or yellow, the preference in some sections being for one, in other sections for the other. The whole kernel meal is commonly stone ground, often on a

[1] U. S. Dept. Agr. 1915, Bul. **215**.
[2] Loc. cit.

Composition of Maize Products of the Same Milling
(Winton, Burnet, and Bornmann)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Acidity
	%	%	%	%	%	%	
White corn:							
Corn	13.52	9.12	3.62	70.50	2.02	1.22	27.5
Grits, coarse	13.07	8.78	0.48	76.78	0.53	0.36	16.4
Grits, fine	12.12	8.66	0.64	77.68	0.48	0.42	16.6
Meal, cream	11.97	7.85	1.41	77.65	0.56	0.56	19.1
Meal, brewers'	11.95	8.00	1.23	77.59	0.64	0.59	18.1
Flour	11.19	6.78	2.87	77.61	0.80	0.75	22.1
Germ	6.64	16.62	23.79	40.30	6.04	6.61	59.3
Germ cake	2.14	20.22	7.26	54.39	7.90	8.09	68.6
Feed (including bran)	11.00	11.69	8.44	60.99	5.03	2.85	52.4
Bran	10.13	8.43	6.71	62.85	9.72	2.16	49.2
Yellow corn:							
Corn	13.45	9.16	5.10	68.89	2.06	1.34	35.4
Meal, bolted, coarse	12.88	9.78	0.90	75.60	0.45	0.39	18.0
Meal, bolted, fine	13.10	9.09	2.19	74.48	0.53	0.61	21.1
Germ	11.29	13.34	18.07	49.25	3.98	4.07	62.5
Bran	10.37	9.06	11.09	57.19	9.68	2.70	66.5

small scale, the degerminated meal is roller ground, on a large scale and by a system analogous to the gradual reduction process of milling.

The analyses by the authors named above, here tabulated, show differences in composition parallel with those of the corresponding products of wheat milling. The figures for acidity were obtained by the method devised by Schindler [1] and employed by Black and Alsberg.[2] The results are in terms of cubic centimeters of normal alkali per kilo of meal. The arbitrary limit of acidity adopted by Schindler was only slightly exceeded in any case when the meal was ground, the higher figures reported being due to changes during the week or so elapsing between the milling and the analysis.

Corn Embryo (Germ).—In addition to the analyses in the foregoing tables, an analysis by Kalning [3] is of interest: protein 15.11, fat 24.36, nitrogen-free extract 48,72, starch 24.75, sugar after inversion 8.00, fiber 5.76, and ash 6.05 per cent in the dry matter.

Winterstein and Wünsche,[4] in their analysis of maize germ contain-

[1] Anleitung zur Beurteilung des Maises, etc. Innsbruck, 1909.

[2] U. S. Dept. Agr., Bur. Plant Ind., 1910, Bul. **199**.

[3] Z. ges. Getreiden, 1917, **9**, 167.

[4] Z. physiol. Chem. 1915, **95**, 310.

ing 96.22 per cent of dry substance, found: fat 53.82, pentose 0.13, and ash 1.37 per cent. The fat contained lecithin 2.11 and unsaponifiable matter 1.81, the figures being percentages of the fat.

Composition of Corn (Maize) Meal of Different Types (Winton, Burnet, and Bornmann)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Acidity *
		%	%	%	%	%	%	
Whole-kernel, white:	11							
Min.	.....	10.17	7.25	3.56	70.60	1.36	1.20	20.7
Max.	.....	13.28	9.41	4.49	74.52	2.19	1.38	42.7
Average	.....	12.18	8.35	4.01	72.19	1.97	1.30	29.0
Undegerminated, bolted, white:	12							
Min.	.....	10.12	7.47	2.75	68.31	0.77	0.86	20.7
Max.	.....	15.09	9.22	5.14	73.76	1.77	1.65	46.0
Average	.....	12.99	8.75	3.90	71.79	1.30	1.27	30.5
Degerminated, bolted, white:	18							
Min.	.....	11.97	5.81	0.70	72.41	0.58	0.35	10.6
Max.	.....	18.28	8.84	2.31	78.40	0.96	0.81	23.0
Average	.....	13.98	6.95	1.43	76.42	0.70	0.52	17.0
Degerminated, bolted, yellow:	6							
Min.	.....	13.01	6.63	0.33	71.98	0.46	0.24	14.0
Max.	.....	17.85	8.63	1.81	76.64	0.76	0.65	19.7
Average	.....	14.95	7.52	0.99	75.48	0.63	0.43	17.0
Low grade ("Standard"), white:	8							
Min.	.....	10.01	7.05	2.83	68.26	0.80	0.85	19.7
Max.	.....	14.65	9.97	5.26	74.39	1.80	1.57	44.5
Average	.....	12.41	8.67	3.89	72.48	1.27	1.28	25.2

* Cc. N alkali required to neutralize the neutral-alcohol extract of 1 kilo of meal.

Respiration.—C. H. Bailey,[1] in experiments with shelled maize, found that moisture determines in large degree the rate of respiration. In northern-grown maize it proceeded more actively than in southern-grown. Immediately after harvesting, the rate was somewhat less than later in the season. Broken, sprouted, and heat-damaged kernels respired more vigorously than sound kernels. An increase in temperature from 27.8 to 37.8° C. nearly doubled the rate.

Proteins.—The principal protein of maize, *zein*, was discovered and named by John Gorham of Harvard University,[2] who, however, did not understand that it was nitrogenous.

Stepf [3] obtained zein in pure form with 15.6 per cent of nitrogen and showed that by repeated solution in alcohol and evaporation it became insoluble in that menstruum.

[1] Minnesota Agr. Exp. Sta. 1922, Tech. Bul. **3.**
[2] Quar. J. Sci. Lit. Arts 1821, **11**, 206.
[3] J. prakt. Chem. 1859, **76**, 88.

Ritthausen [1] corroborated Stepf's determination of nitrogen and made complete ultimate analyses of zein and a protein soluble in dilute alkali solution of which he found 0.5 per cent in the grain.

Chittenden and Osborne [2] and Osborne [3] repeated the work of the former investigators and also extracted and analyzed minor proteins.

Osborne's determinations of the percentage amounts of the different proteins of the maize kernel follow:

	Nitrogen	Protein
	%	%
Proteose * (soluble in water)	0.0102	0.06
Globulins (soluble in salt solution):		
Maysin (coagulable)	0.0417	0.25
Edestin (mostly non-coagulable)	0.0181	0.10
Very soluble globulin	0.0061	0.04
Zein (soluble in alcohol)	0.8065	5.00
Glutelin (soluble in alkali)	0.4983	3.15
True proteins	1.3809	8.60
Nitrogen insoluble in alkali	0.1645	1.03
	1.5454	9.63

* No albumin appeared to be present.

Osborne [4] states that whereas most of the prolamines are little soluble in alcohol of less than 50 per cent or more than 90 per cent strength, *zein* readily dissolves in alcohol of 92 to 93 per cent. Osborne and Harris [5] found the specific rotation of zein in 90 per cent alcohol to be $-28.0°$; Kjeldahl,[6] using 75 per cent alcohol, $-35.0°$.

Jones and Csonka [7] found in maize two glutelins, α and β. The total glutelin is first precipitated from the alkaline extract by hydrochloric acid added to *p*H 6.7 to 6.8. The precipitate is again dissolved in dilute sodium hydroxide and *α-glutelin* precipitated by ammonium sulphate added to 3 per cent saturation. Its isoelectric point (*p*H) is 6.45. From the supernatant liquid *β-glutelin* is precipitated by ammonium sulphate added to 16 per cent saturation.

[1] Ibid. 1869, **106**, 471.
[2] Am. Chem. J. 1891, **13**, 453, 529; 1892, **14**, 20.
[3] Conn. Agr. Exp. Sta. Rep. 1896, p. 391.
[4] Vegetable Proteins, 1912, p. 34.
[5] J. Am. Chem. Soc. 1903, **25**, 842.
[6] Bied. Centr. 1896, **25**, 197.
[7] J. Biol. Chem. 1928, **78**, 289.

The specific rotation at 20° of α-glutelin as found by Csonka, Horn, and Jones [1] is $-72.6°$. β-glutelin being present in small amount, its rotation and other properties were not determined.

Ultimate Composition.—Chittenden and Osborne also Osborne found that preparations of the proteose and the very soluble globulin were not uniform in composition owing, it was believed, to alteration in the process. The range of nitrogen in the proteose was 15.78 to 17.28, and in the globulin, 15.16 to 15.69 per cent. Ultimate analyses of the four proteins of constant composition are here given.

Ultimate Composition of Maize Proteins (Chittenden and Osborne)

	Alkali-soluble protein	Zein	Maysin	Edestin
	%	%	%	%
Carbon	51.26	55.28	52.66	51.71
Hydrogen	6.72	7.27	7.02	6.85
Nitrogen	15.82	16.09	16.76	18.12
Sulphur	0.90	0.59	1.30	0.86
Oxygen	25.30	20.77	22.26	22.46
	100.00	100.00	100.00	100.00

Amino Acids of Maize Proteins.—The products of hydrolysis of zein and maize glutelin have been determined by Osborne and Clapp,[2] following in the main the methods of Fischer and Kossel. Their results, amended in the case of zein by later figures obtained by Osborne and Liddle,[3] appear on the following page.

The absence of tryptophane in zein is often cited as indicating a nutritional deficiency of this protein.

Dakin [4] developed a new method of separation of the products of hydrolysis, using butyl alcohol, by means of which more accurate quantitative results are obtained. He later [5] isolated a new acid of the dicarboxylic group, *hydroxyglutamic acid*, the β form of which he has synthesized. Employing his method,[6] he separated the following per-

[1] Ibid. 1930, **89**, 267.
[2] Am. J. Physiol. 1907, **20**, 477.
[3] Ibid. 1910, **26**, 295.
[4] Biochem. J. 1918, **12**, 290.
[5] Ibid. 1919, **13**, 398.
[6] Z. physiol. Chem. 1923, **130**, 159.

PRODUCTS OF HYDROLYSIS OF MAIZE PROTEINS (OSBORNE ET AL.)

	Maize glutelin	Zein
	%	%
Glycocoll	0.25	0.00
Alanine	.....	9.79
Valine	.....	1.88
Leucine	6.22	19.55
Serine	.....	1.02
Aspartic acid	0.63	1.71
Glutaminic acid	12.72	26.17
Tyrosine	3.48	3.55
Phenylalanine	1.74	6.55
Proline	4.99	9.04
Tryptophane	+	0.00
Arginine	7.06	1.55
Lysine	2.93	0.00
Histidine	3.00	0.82
Ammonia	2.12	3.64
Total	45.14	85.27

centages of amino acids in zein: alanine 3.8, leucine 25, glutamic acid 31.3, β-hydroxyglutamic acid 2.5, tyrosine 5.2, and phenylalanine 7.6 per cent. In later experiments [1] he obtained 0.84 per cent of pure valine which in his earlier work escaped detection. If these figures, excepting the valine, also those of Jones, Gersdorff, and Moeller [2] who obtained 0.85 per cent of cystine but no tryptophane, are substituted for those of Osborne and Liddle, as shown in the table above, the footing will be 95.9 per cent.

The *Nitrogen Distribution of* α-glutelin, as found by Jones and Csonka,[3] was: amide 7.73, cystine 2.04, arginine 15.11, histidine 2.81, lysine 7.99, and amino in filtrate from bases 59.64 per cent.

Nitrogen Distribution in Maize Kernel.—Nollau [4] determined the distribution of the nitrogen in maize kernel by Van Slyke's method with the following results: humin nitrogen 7.00, cystine nitrogen 4.06, arginine nitrogen 16.19, histidine nitrogen 4.45, lysine nitrogen 8.53, monoamino nitrogen 49.69, non-amino nitrogen none, and amide nitrogen 4.63; total nitrogen 94.55 per cent.

[1] J. Biol. Chem. 1924, **61**, 137.
[2] Ibid. 1924, **62**, 183.
[3] Loc. cit.
[4] J. Biol. Chem. 1915, **21**, 611.

Free Amino Acids, Acid Amides, and Polypeptides.—Determinations by Jodidi [1] appear in the following table:

DISTRIBUTION OF NON-PROTEIN NITROGEN IN DENT MAIZE (JODIDI)

	Acid amide N	Amino acid N	Peptide N
	%	%	%
In oven-dried kernel:			
Four County	0.032	0.045	0.069
U. S. Selection	0.019	0.040	0.050
Hall Gold Nugget	0.021	0.051	0.036
In total nitrogen:			
Four County	1.88	2.65	4.06
U. S. Selection	1.19	2.52	3.14
Hall Gold Nugget	1.44	3.49	2.47

Fat.—Maize oil is as distinctly an American product as maize itself is an American cereal. In its purified form it is adapted for use both as a salad oil and a shortening.

Physical and Chemical Values.—Hopkins [2] found: specific gravity at 15° C. (3 samples) 0.9245 to 0.9262, iodine number (4 samples) 121.5 to 123.1, and volatile fatty acids (1 sample) none. His calculation showed the composition of the oil to be: *cholesterol* 1.37, *lecithin* 1.49, *stearin* (?) 3.66, *olein* 44.85, and *linolin* 48.19 per cent.

Tolman and Munson [3] summarized the values obtained by them (4 samples) and others for commercial corn oil as follows:

	Sp. gr. 15.5° C.	Ref. index 15.5° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, m. pt.	Fatty acids, titer	Fatty acids, free
						°C.	°C.	%
Min	0.9213	1.4760	56.0	188.0	111.1	16.0	13.0	1.12
Max	0.9255	1.4768	89.2	193.4	123.9	23.0	16.0	3.60

Klimont [4] obtained the following results: specific gravity at 15° C.

[1] J. Agr. Res. 1925, **30**, 587, 989.
[2] Illinois Agr. Exp. Sta. 1898, Bul. **53**.
[3] U. S. Dept. Agr., Bur. Chem., 1903, Bul. **77**.
[4] Pharm. Post 1918, **51**, 561.

0.920, refractive index 1.4740, saponification number 189.7, and iodine number 119.9.

Corn oil pressed by means of an " oil expeller " from corn germs produced by the " dry process " was examined by Baughman and Jamieson [1] both as to its physical and chemical constants and its composition. Their figures for the physical and chemical values are: specific gravity 25°/25° 0.9185; refractive index at 20° C. 1.4717; saponification number 187.3; iodine number (Hanus) 117.2; acid number 2.5; acetyl number 10.0; saturated acids, determined 12.3 per cent (iodine number 12.3), corrected, 11.2 per cent; unsaturated acids and unsaponifiable matter, determined 83.3 per cent (iodine number 136.9); unsaturated acids, corrected, 82.5 per cent (iodine number 137.2); unsaponifiable matter 1.7 per cent (iodine number 113.5).

Composition.—The foregoing authors give the composition of the oil as follows:

Glycerides of:	%
Lignoceric acid	0.2
Arachidic acid	0.4
Stearic acid	3.5
Palmitic acid	7.7
Oleic acid	45.4
Linolic acid	40.9
Unsaponifiable matter	1.7
	99.8

Sterols.—The sterol of the *embryo oil* with a melting point of 137 to 137.5°, which Hopkins [2] called cholesterol, was shown by Gill and Tufts [3] to be the sitosterol of Burian.[4]

Anderson and Moore [5] found that the unsaponifiable matter, amounting to 2.01 per cent of the crude oil and 1.68 per cent of the refined oil, consisted largely of this substance, the melting point being practically the same as reported by Hopkins, and the optical rotation −34.38°.

Further investigation by Anderson and Shriner [6] showed that the crystalline substance consists of (1) *dihydrositosterol* ($C_{27}H_{47}OH$), forming about 1.6 per cent of the crude crystals, (2) a small amount of *stigmasterol* ($C_{30}H_{50}O$), and (3) a mixture corresponding to sitosterol

[1] J. Am. Chem. Soc. 1921, **43**, 2696.
[2] Ibid. 1898, **20**, 948.
[3] Ibid. 1903, **25**, 251.
[4] Monatsh. 1897, **18**, 551.
[5] J. Am. Chem. Soc. 1923, **45**, 1944.
[6] Ibid. 1926, **48**, 2976.

$C_{27}H_{45}OH$ made up of *α-*, *β-*, and *γ-sitosterol* of which only the γ form, melting at 145 to 146° and polarizing −42.43°, was secured in a condition of purity.

The *endosperm oil*, according to Anderson,[1] contains some free phytosterol with melting point 137 to 137.5°, and optical rotation −32.23°. After saponification of the oil the unsaponifiable matter consists of (1) optically active *dihydrositosterol* ($C_{27}H_{47}OH \cdot H_2O$)with larger and denser crystals than those of ordinary sitosterol, melting at 138 to 139°, (2) a rather large amount of ordinary *sitosterol*, and (3) yellow-brown *oily matter*. Further purification of the sitosterol by Anderson and Nabenhauer [2] yielded crystals melting at 138 to 139° and having a rotation of −36.69°.

Carbohydrates.—Gorham in 1821 determined the carbohydrates in maize, finding: sugar 1.59, gum 1.92, fiber 3.30, and starch 84.60 per cent. Although regarded as chiefly of historic interest, his figures are not so unreasonable as many secured in recent years. They are certainly nearer the truth than those of Archbold,[3] namely: water 11.20, gum and sugar 2.90, cellulose 16.40, and starch 54.80 per cent.

The presence of *sucrose* in maize was demonstrated by Washburn and Tollens,[4] who obtained an amount of the crystalline substance from field corn equivalent to 0.08 per cent, and from sweet corn, equivalent to 0.52 per cent. These figures of course do not represent the full amount present. In sweet corn they found by accurate analytical methods 2.26 per cent of sucrose and 1.47 per cent of *invert sugar*, total 3.73 per cent, but in field corn the total sugar was usually less than 1 per cent.

Following Washburn and Tollens' method, examination of 27 samples of sweet corn at the Massachusetts Station yielded the following results: sucrose 0.78 to 5.60, aver. **3.51**; invert sugar 0.69 to 2.93, aver. **1.76**; and total sugar 2.87 to 8.53, aver. **5.27** per cent.

Stone [5] reported in field maize: sucrose 0.24, invert sugar none, dextrin 0.28, pentosans 4.99, and fiber 1.93 per cent. His obviously erroneous figures for starch need not be given. His figures for pentosans are little lower than he had previously given [6] for bran, which is the chief seat of this carbohydrate, but Tollens and Flint [7] later found over 38 per cent in this material.

[1] J. Am. Chem. Soc. 1924, **46**, 1450.
[2] Ibid. 1924, **46**, 2113.
[3] J. Soc. Chem. Ind. 1887, **6**, 84.
[4] Ann. Chem. 1890, **257**, 156.
[5] U. S. Dept. Agr., Off. Exp. Sta. 1896, Bul. **34**.
[6] B. deut. chem. Ges. 1890, **23**, 3791.
[7] Ibid. 1892, **25**, 2916.

See Sweet Corn for comparison of sugar, gum, and starch in dent, flint, and sweet varieties.

Pentosans and *Methylpentosans* have been determined by Porst[1] in the parts of the maize kernel and in the products and by-products of the starch and glucose industry. The grade of maize used contained about as follows: endosperm 85.7, germ 7.5, hulls 6.8 per cent. The percentages of pentosan and methylpentosan in these (and the commercial products made from them), calculated to the dry basis, were: endosperm 1.45 and 0.74, germ 0.63 and 0.02, and hulls 3.31 and 0.41 per cent, respectively. In the commercial products and by-products he found pentosan and methylpentosan in the following percentages:

Pentosan and Methylpentosan in Maize Products and By-Products (Porst)

	Pentosan	Methylpentosan
	%	%
Germ meal	11.43	0.57
Oil cake	23.00	0.85
Gluten meal	4.06	0.50
Hulls	39.96	2.79
Corn soluble	1.74	0.46
Gluten feed	18.58	1.21
Green starch	0.98	1.40
Food starch	0.48	1.21
Corn syrup (42 per cent glucose, dry basis)	0.78	0.90
Anhydrous sugar (97 per cent glucose, dry basis)	0.72	1.18
Bread sugar (94.5 per cent glucose, dry basis)	0.66	0.98
Hydrol (mother liquor of last)	0.86	1.79
No. 80 sugar (92 per cent glucose, dry basis)	0.68	1.06
No. 70 sugar (86. 5 per cent glucose, dry basis)	0.72	1.15

Ver Hulst, Peterson, and Fred,[2] in studies of pentosans and pentoses in the maize plant during different stages of development, found 7.4 per cent of pentosans in the kernel and 31.8 per cent in the cob. When the kernel was in the milk the cob contained 0.25 per cent of free pentoses and practically the same when in dent. The kernels when in dent contained 0.18 per cent of free pentoses.

Porphyratin.—Fischer and Schwerdtel[3] obtained porphyrin from maize as well as other cereals. This may exist in the grain in the form of porphyratin as claimed by Schumm and Mertens. See Oats.

[1] Eighth Int. Cong. Appl. Chem. 1912, **13**, 205.

[2] J. Agr. Res. 1923, **23**, 655.

[3] Z. physiol. Chem. 1926, **159**, 120.

Phosphorus-Organic Compounds. *Lecithin.*—Schulze [1] found only 0.25 per cent of lecithin in maize kernel, which is only half that of wheat. This seems remarkable in view of the higher oil content. Judging from Hopkins' analysis [2] of maize oil, over half of the lecithin is expressed with the fatty oil.

Phytin.—According to Anderson,[3] the phytin corresponds in composition with inosite hexaphosphoric acid, $C_6H_{18}O_{24}P_6$, rather than with phytic acid, $C_6H_{24}O_{27}P_6$.

Koehler [4] finds that 86 to 90 per cent of the total phosphorus is in the embryo, and he gives the amounts of phytin phosphorus in the different parts.

Rather [5] found that the principal inosite phosphoric acid of maize corresponds neither to the hexaphosphoric acid nor to phytic acid but to inosite pentaphosphoric acid, $C_6H_6(OH)(H_2PO_4)_5$. He states that 75 per cent of the phosphorus of the kernel is in this form, 18 per cent in inorganic combination, and 7 per cent in other combination.

Nucleic Acid (Nuclein).—Doubtless present. See Wheat.

Color.—Studies by Remy [6] indicate that the substances imparting the color to red and violet kernels belong to the anthocyanin group whereas the color of yellow kernels is a flavone derivative. He also found that the general composition of the kernel was not materially influenced by the color.

Enzymes.—*Maltase* is present in large amount according to Wierzchowski.[7] Huerre [8] distinguishes maltases with optimum activity at relatively high and low temperatures.

Protease.—Giesen [9] reports 0.28 per cent, calculated as trypsin, the optimum temperature being 30 to 40° C.

Peroxidase.—Coupin [10] obtained a blue color by the benzidine test.

Mineral Constituents.—The earlier analyses made by Way and Ogston[11] in England and by Wolff [12] in Germany are remarkably accurate and concordant, particularly as regards the content of soda.

[1] Landw. Vers.-Stat. 1897, **49**, 203.
[2] Loc. cit.
[3] J. Biol. Chem. 1914, **17**, 141.
[4] Bul. intern. acad. Polanaise, 1926, B, 707.
[5] J. Am. Chem. Soc. 1918, **40**, 523.
[6] Z. Unters. Nahr.-Genussm. 1922, **44**, 209.
[7] Biochem. Z. 1913, **57**, 125.
[8] Compt. rend. 1909, **148**, 505.
[9] Inaug. Dis. Bern, 1909.
[10] Compt. rend. 1925, **180**, 685.
[11] Liebig: Chemie in ihre Anwendung auf Agricultur, 1865, **1**, 384.
[12] Aschenanalysen, 1880.

Their results, in the latter case the average of 15 analyses, are as follows:

Composition of Dent Maize Ash

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
W. and O.	28.4	1.7	0.6	13.6	0.5	53.7	trace	1.6	
Wolff	29.8	1.1	2.2	15.5	0.8	45.6	0.8	2.1	0.9

Results published by Latshaw and Miller[1] in terms of percentages of the elements in the water-free kernels and cob, harvested when in the dough, follow:

	K	Ca	Mg	Fe	Al	Mn	P	S	Si	Cl
	%	%	%	%	%	%	%	%	%	%
Kernels	0.42	0.025	0.20	0.043	0.023	0.037	0.34	0.140	0.016	0.120
Cob	0.46	0.022	0.11	0.025	0.052	0.031	0.94	0.021	1.330	0.033

Minor Mineral Constituents. *Iron.*—Yellow corn meal 11.5, whole sweet corn 29 mg. per kilo (Sherman).[2] Maize, white 17, yellow 26 mg. per kilo (McHargue).[3] Maize, white, endosperm and seed coats 32.5, germ 224; yellow, endosperm and seed coats 28, germ 146 mg. per kilo, dry basis (McHargue).[4]

Aluminum.—Maize 0.5 mg. per kilo, dry basis (Bertrand and Lévy).[5]

Manganese.—Maize, white 7, yellow 4 mg. per kilo (McHargue).[3] Maize, white, endosperm and seed coats 2, germ 27.5; yellow, endosperm and seed coats 2.5, germ 30 mg. per kilo, dry basis (McHargue).[4] Maize, 5.88 mg. per kilo, air dry basis (Quartaroli).[6] Maize, 5 varieties, 9 to 18 mg. per kilo, dry basis (Davidson).[7]

Copper.—Maize 6.8 mg. per kilo air dry basis (Guerithault).[8] Maize, white, endosperm and seed coats trace, germ 3.5; yellow, endosperm and seed coats 0.5, germ 15 mg. per kilo, dry basis (McHargue).[4] Maize 2.21 mg. per kilo, air dry basis (Quartaroli).[6]

Zinc.—Maize, white, endosperm and seed coats 41.6, germ 22.4; yellow, endosperm and seed coats 64, germ 272 mg. per kilo, dry basis (McHargue).[4] Maize,

[1] J. Agr. Res. 1924, **27**, 845.
[2] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.
[3] J. Agr. Res. 1923, **23**, 395.
[4] J. Am. Soc. Agron. 1925, **17**, 368.
[5] Compt. rend. 1931, **192**, 525.
[6] Ann. chim. appl. 1928, **18**, 47.
[7] Cereal Chem. 1929, **6**, 128.
[8] Compt. rend. 1920, **171**, 196.

whole 25.2, degerminated 4 mg. per kilo, air dry basis (Birckner).[1] Maize whole seed 20.4 mg. per kilo, dry basis (Bertrand and Benzon).[2]

Arsenic.—Maize kernel 0.3 mg. per kilo (Jadin and Astruc).[3]

FLINT MAIZE

Zea Mays var. *præcox* L. = *Z. indurata* Sturt.

Fr. Maïs. Sp. Maiz. It. Maiz. Ger. Gemeiner Mais.

The type of maize known in America as flint corn and in central European countries as common maize is distinguished from dent maize by its rounded form and the absence of an indentation at the top. White, yellow, and red varieties are cultivated in certain sections of the United States, particularly in the eastern section. As in the case of the dents, flint varieties differ as to the proportion of horny to floury endosperm.

MICROSCOPIC STRUCTURE.—Practically the same as of dent maize.

CHEMICAL COMPOSITION.—See Dent Maize for summary of proximate analyses and Sweet Corn for comparison of sugar, gum, and starch in dent, flint, and sweet varieties.

POP CORN

Zea everta Sturt.

Sp. Palomitas de maiz.

The name " pop " is indicative more of suitability for preparing the American confection known as pop corn than of distinctive botanical characters. Nevertheless, varieties suited for popping are grouped together.

Popping of corn as carried out in factories, by street venders, and in the household consists of heating the corn in a covered wire cloth or thin metal container over a brisk fire with constant agitation. If the heat is too high the corn burns without popping. After a few moments' heating each kernel explodes and turns inside out into an irregular snow-white mass, the whole being several times larger than the original kernel. To secure the proper result, the kernel must be cured but not too dry, since a certain amount of moisture is essential for the swelling of the starch.

[1] J. Biol. Chem. 1919, **38**, 191.
[2] Bul. soc. hyg. aliment. 1928, **16**, 457.
[3] Compt. rend. 1914, **159**, 268.

MACROSCOPIC STRUCTURE.—The *kernels* are small with a minimum of floury endosperm. In some varieties the kernels are rounded at the top as in the flints; in others, distinctly beaked. The so-called " rice " variety has exceedingly slender kernels.

MICROSCOPIC STRUCTURE.—The only marked histological difference from flint corn is that the *hypoderm* is not quite so strongly developed. Usually the layer is 7 to 10 cells thick and measures 80 to 120 μ.

As a result of popping, the *starch grains* become swollen to two or three times their normal diameter and the hilum becomes indistinct, but most of the grains in the horny endosperm preserve their polygonal form.

Chief Structural Characters.—Kernel like that of flint maize but smaller and with more horny endosperm. Microscopic structure nearly the same as of dent and flint maize.

CHEMICAL COMPOSITION.—See Dent Maize for summary of proximate analyses.

Little has been done on the physics and chemistry of popping. It is well known that it is due to the sudden expansion of water in the cells.

Wilbert [1] found that if the moisture is insufficient as in old corn the corn does not pop properly but at best only splits open. Quick heating is essential. By slow heating the kernel may be dried up and parched without popping. It is the cells in the denser part of the kernel, not the basal cells, that explode.

According to Carr and Ripley,[2] popping causes an increase in ether extract, soluble starch, dextrin, and (slightly) fiber, but a decrease in total starch.

SOFT MAIZE

Zea amylacea Sturt.

The entire absence of horny endosperm characterizes this group. Cuzco, the best-known variety, has kernels reaching or exceeding 2.5 cm. long and 1.8 cm. wide. It is grown to some extent in the warmer regions of the United States.

MICROSCOPIC STRUCTURE.—Although the kernels are exceptionally large, the pericarp is less strongly developed than in dent and flint varieties, seldom exceeding 100 μ in thickness. The *hypoderm* is 6 to 8 cells thick, most of the cells being compressed. *Cross cells* and *tube cells* are not strongly developed.

[1] Am. J. Pharm. 1903, **75**, 77.

[2] Indiana Acad. Sci. Proc. 1920, p. 261.

The outstanding characteristic is the *starch* of the floury endosperm with rounded grains up to 32 μ or even larger and the absence of polygonal grains. The hilum of itself is not conspicuous, but its central location is often well marked by radiating fissures.

MICROSCOPY OF SOFT MAIZE PRODUCTS. *Corn Meal* made from soft varieties differs from ordinary corn meal in that the large starch grains are throughout rounded or spherical, although, if by crossing or selection a horny endosperm is present in the kernel, the corn meal will contain a corresponding amount of polygonal grains.

Corn Starch.—Soft corn would appear to be well suited for starch manufacture although it is not so used on a commercial scale. Such a product, because of the nearly spherical grains and the practical absence of polygonal grains, would indeed be unique among commercial starches.

Chief Structural Characters.—Kernel large, floury. Pericarp less strongly developed than in dents and flints. Starch grains rounded, not polygonal.

SWEET CORN

Zea Mays L. var. *saccharata* Sturt.

Fr. Maïs sucré. Ger. Zuckermais.

When gathered "in the milk," sugar or sweet corn is distinctly a vegetable and is described in the section on Vegetables. The whole plant is grown to some extent as a green fodder and for silage. Occasionally, the mature shelled kernel is used for feeding, but it is best known as the seed for planting and its structure is of interest chiefly to seed experts. Because of certain physical, chemical, and structural differences from common field maize the mature kernel is given a place in this chapter.

MACROSCOPIC STRUCTURE.—The different varieties differ greatly in the form, size, and color of the *kernel* and the ratio of kernel to cob, but all have the distinguishing characteristic of a much shrunken and deeply wrinkled kernel and a peculiar brittle, glassy condition of all or nearly all the starchy endosperm. To the eye, the brittle *endosperm* resembles in appearance the horny endosperm in other varieties, but it differs not only in physical characters but also in chemical composition, soluble carbohydrates displacing starch to a large extent.

In some common varieties, such as Golden Bantam, Early Dawn, Red Cob Cory, Mammoth White Cory, Mammoth Sugar, and Black Mexican, the kernel is flat, often broader than long, and usually well rounded at the tip, whereas in others, notably Evergreen and especially

Country Gentleman, the kernel is slender, often several times as long as broad. The common color is white, but Golden Bantam is yellow, Black Mexican is blue, and other varieties range from pink to red. The location of the color is the same as in dent and flint maize.

MICROSCOPIC STRUCTURE.—Hanausek [1] made an exhaustive study of the structure and development of sweet corn, particularly with reference to the starch and soluble carbohydrate. Our own studies of nine of the best-known American varieties, including those named above, corroborate his statements as to the form of the starch grains and the reaction with iodine of the carbohydrate soluble in water.

Pericarp.—The distinction from dent and flint maize lies in the smaller number of rows of well-developed *hypoderm* cells seen in cross section and the consequent thinner pericarp. Instead of eight to twelve rows of hypoderm cells with distinct lumen and a pericarp thickness of 150 to 175 μ found in dent and flint varieties, only two to four cells and a thickness of less than 100 μ are the common rule for sweet corn.

Spermoderm and Perisperm.—As in dent and flint maize.

Endosperm.—The cells of the *aleurone layer* generally show in cross sections radial elongation. This distinction from dent and flint varieties is usually well marked although not in all parts of the kernel. Cross sections of Black Mexican sweet corn furnish a beautiful demonstration of blue coloring matter in the aleurone cells, the color with sodium hydroxide changing first to green and then being discharged, whereas with acid chloral hydrate solution it becomes a beautiful red.

Chief interest centers in the *starch cells.* These show characteristics markedly distinct from those of all smooth varieties of maize. The peripheral layer contains minute *starch grains* of rounded form intermixed further inward with what appear at first glance to be round or oval grains of about the size of the individual grains in dent and flint varieties. These on careful examination are seen to be for the most part not individual grains but aggregates of the rice type. Further inward, particularly on the opposite side from the embryo, the component grains, as well as the aggregates, differ greatly in size and assume a variety of curious forms. In addition to ovals there are rod-shaped aggregates of three or more members, the end grains being truncated and the center grains quadrilateral, often with spool-like constrictions. Bell-shaped individuals occur in branching aggregates. If floury endosperm is present, which is exceptional and then in small amount, round grains of the usual maize type may be present.

Throughout the inner portion of the parenchyma, often beginning with the cells next to the outermost, starch grains are present in small

[1] Archiv. Chem. Mikros. 1911, 4, 213; 1914, Heft 2.

numbers or are entirely absent, and their place is taken by a *soluble carbohydrate*, staining coffee-brown with iodine in potassium iodide and because of its intensity obscuring the other tissues. When the colored solution is removed with water, such starch grains as are present show their blue color while a protein deposit clings to the walls and often forms a fine, more or less granular, network throughout the cell. The cell walls are wavy as seen on the cut surface and striated as seen in surface view, both appearances being due to the shrinking of the tissues on drying. The color with iodine solution indicates that the soluble carbohydrate is a dextrin or mixture containing one or more dextrins.

Concerning the formation of the starch and its degeneration, Hanausek states that a portion of the protoplasm becomes differentiated into a thick body with rows of granules (yellow with iodine), together with what appear to be drops, along the periphery. Within these granules large coherent masses are formed in which starch grains develop. Usually a single large grain or a group of these and a group of small grains occur side by side, but he was unable to determine whether the two groups unite or remain separate. Finally, some of the starch grains go into solution and the remaining grains move to the cell walls while the residual matter forms the meshes of the network mentioned above. He thus demonstrated that the soluble carbohydrate resulted from the solution of the starch grains, doubtless through the agency of an enzyme, and is not to be confused with the soluble carbohydrate from which the starch grains crystallized.

Chief Structural Characters.—Kernel shrunken; endosperm horny. Hypoderm of fewer cell layers than in dent and flints. Aleurone cells radially elongated; starch cells containing large and small starch aggregates and soluble carbohydrate staining coffee-color with iodine.

CHEMICAL COMPOSITION.—See Dent Maize for summary of proximate analyses, and Sweet Corn (under Vegetables, Volume II) for changes during development.

Carbohydrates. *Sugar, Gum, and Starch.*—Soon after the first experiment station was established in the United States, Kedzie [1] and Collier [2] published analyses covering not only the six proximate constituents ordinarily determined, but also sugar, gum, and starch, as well as (in Collier's analyses) alcohol soluble (zein) and insoluble proteins. With due allowance for methods of analysis and terminology, their figures for the carbohydrates, or rather carbohydrate groups, given below, illustrate well the difference in composition of common (dent and flint) maize and sweet corn and supplement the interesting microscopic char-

[1] Michigan Bd. Agr. Rep. 1878 and 1879.
[2] U. S. Dept. Agr. Rep. 1878.

acteristics first noted by T. F. Hanausek as given herewith under the head of Microscopic Structure.

CARBOHYDRATES OF SWEET CORN

	Samples	Sugar	Gum	Starch
	%	%	%	%
Dent:				
Kedzie	8	3.59–2.31	5.38– 2.18	62.94–58.05
Collier	3	2.75–1.95	2.80– 1.73	70.81–64.07
Flint:				
Kedzie	4	3.78–2.40	6.16– 1.21	63.50–57.47
Collier	17	2.87–1.47	3.18– 1.37	69.65–62.26
Sweet:				
Collier	7	6.77–4.80	22.65–14.50	46.08–39.46

CHINESE WAXY MAIZE

In this variety the kernel is small, flattened or angular, without dent or wrinkles, and of a waxy appearance. The endosperm is of peculiar texture and contains, as noted by Weatherwax,[1] grains of a carbohydrate giving a red-brown or purple color with iodine. In other histological characters the kernel is practically the same as dent maize. The sample examined was furnished by Mr. J. H. Kempton, of the Bureau of Plant Industry.

CHEMICAL COMPOSITION. **Fat.**—In studying the fat metabolism of non-waxy and waxy varieties of maize, Abegg [2] obtained the following average results:

	Whole kernel	Endosperm	Embryo
	%	%	%
Fat:			
Non-waxy	6.50	1.05	34.0
Waxy	7.30	1.50	34.3
Acid number:			
Non-waxy	13.0	45.6	4.2
Waxy	34.0	82.0	4.1

In the above and other series of experiments the following average values of the endosperm fat were found: saponification number, non-

[1] Genetics, 1922, **7,** 568.

[2] J. Agr. Res. 1929, **38,** 183.

waxy 177, waxy 200; acid number, non-waxy 60, waxy 100; ester value (saponification number less acid number), non-waxy 111, waxy 100.

Carbohydrates.—According to Brink,[1] waxy and non-waxy maize contain equal proportions of α- and β-*amylase*. Malt amylase hydrolyzes the starch of waxy maize more slowly than non-waxy, and the intermediate products have a lower rotatory power. Purified starch from non-waxy maize contains twelve times as much organic phosphorus as that from waxy maize.

Lampe and Meyers [2] state that the liquid portion of the carbohydrate globules precedes the appearance of the grains and is always in excess. No reversal of the process was noted.

The fact that the endosperm of waxy maize is rich in *erythrodextrin* is regarded by Weatherwax [3] as of importance in genetic analysis.

POD MAIZE

Zea Mays L. var. *tunicata* St. Hil. = *Z. tunicata* Sturt.

Fr. Maïs tuniqué. Ger. Spelzenmais.

Studies of pod or husk maize are of value chiefly because they throw light on the origin of ordinary maize and the relationship with allied species. The sample examined was kindly furnished by Mr. J. H. Kempton, of the Bureau of Plant Industry.

MACROSCOPIC STRUCTURE.—The appearance of the ear of maize is lost owing to the loose arrangement in a short spike and the husk-like development of the *empty glumes* as well as of the flowering glume and palet of the sterile flower. Because of the chaffy envelopes the spikelet reaches 3 to 4 cm. in length. The *flowering glume* and *palet* of the fertile flower are thin and membranous as in common maize. The *kernel* itself is well rounded but not unlike certain flint varieties in form and structure.

MICROSCOPIC STRUCTURE.—Empty Glumes.—The *outer epiderm* on the thick portion of the glumes, though the same in general structure as in dent maize, shows better the true significance of the non-beaded cells. These latter when occurring singly are hair scars (round cells); when in pairs, one is a hair scar, the other the accompanying cell which may or may not have the characteristic crescent form so common in the floral envelopes of the cereals and other grasses. In some parts the hairs are still attached. These are both unicellular with thick walls

[1] Biochem. J. 1928, **22**, 1349.
[2] Science 1925, **61**, 290.
[3] Loc. cit.

or jointed with thin walls, in both cases with lumen broader than the walls.

The thin edges have the same structure as in dent maize.

Flowering Glumes and Palets.—As in dent maize.

Pericarp, Spermoderm, Perisperm, and Endosperm.—These are as in dent maize, but the *hypoderm* in specimens examined is not so strongly developed and the *starch grains* seldom exceed 20 μ. The *aleurone cells* are often radially elongated.

Chief Structural Characters.—Kernel enveloped by enlarged chaffy envelopes.

Hypoderm thinner and starch grains smaller than in dents and flints. Aleurone cells often radially elongated.

TEOSINTE

Euchlæna mexicana Schrad.

Fr. Teosinté. Ger. Teosinte.

This cereal, a native of Mexico, is the nearest known relative of maize; in fact, some authorities regard maize as a derivative of teosinte or a hybrid of teosinte with an unknown species. Weatherwax [1] has discredited this theory. Like maize, only one species of the genus is generally recognized, although there are marked varieties. The plant is used as green forage in subtropical America. In northern regions it does not ripen the seed but is grown as an ornamental. It is treated here chiefly because of its relationship to maize.

MACROSCOPIC STRUCTURE.—The plant resembles maize in general appearance and the nature of the staminate inflorescence, but the pistillate inflorescence is strikingly different, the thick woody cob being replaced by a jointed *rachis* clasping alternately single spikelets, forming a dense two-rowed spike enclosed in a leafy sheath. The joints of the rachis are described by Scribner and others as empty glumes, which they indeed resemble, but their true nature has been demonstrated by Weatherwax [1] who has also noted the presence of a rudimentary spikelet alongside of each perfect one, thus making the spike really four-rowed. At maturity each joint with its spikelet separates as a seed-like body, the convex surface of the rachis and the exposed dorsal side of the *lower empty glume* being white, brown, or spotted, hard, and lustrous. An oblique truncation with a dull scar in the center at each end of the rachis joint, the two being nearly at right angles to each other, gives the whole a triangular or trapezoidal form.

[1] Bul. Torrey Bot. Club. 1918, **45**, 309.

The *rachis* in the center clasps over the edges of the somewhat thinner but hard *lower empty glume* and entirely conceals the much thinner cartilaginous *upper empty glume* beneath it. On the same side as the upper empty glume (corresponding to the embryo side of the kernel) is the membranous *flowering glume* of the fruit, and on the other side of the kernel is its membranous *palet*. Between the lower empty glume and the palet of the fruit may usually be found two membranous envelopes, the *flowering glume* and *palet* of an abortive flower.

Notwithstanding the difference in appearance, the same number of envelopes and in the same position occur in teosinte as in maize.

The *kernel* freed from the envelopes is 6 mm. or less long, rounded on the ventral (embryo) side, nearly straight on the dorsal side, short beaked, and brown in color.

MICROSCOPIC STRUCTURE.—The tissues of the rachis and chaff resemble in structure those of the corresponding parts of maize. The pericarp and seed seem to bear closer structural relations to sorghums than to maize.

Rachis.—There are two *epiderms* on the rachis, one on the convex, the other on the concave surface, whereas in maize owing to the consolidated nature of the cob there is but one. The epiderm on the convex side, as seen in surface view, consists for the most part of porous, thick-walled, sharply polygonal cells with straight middle lamellæ, arranged in longitudinal rows. Most of these cells are transversely elongated.

On the concave side the porous cells are less distinct in form, more often longitudinally elongated and alternate with twin cells or less often round cells. In cross section the layer is not so thick as the epiderm on the convex side. It is this epiderm that corresponds to that on maize cob.

Beneath the epiderm on the concave side is a *woody zone* like that in maize cob, but the isodiametric cells pass into the epiderm on the convex side, whereas in maize they adjoin the pith.

Empty Glumes.—*Epidermal cells* like those of the convex side of the rachis occur on the outer side of the empty glumes, but in parts the walls and particularly the middle lamellæ are more or less wavy and non-porous. Thinner-walled cells occur at intervals, usually singly, less often in company with a crescent cell. The non-porous cells are hair scars, and the *hairs* or their bases sometimes persist. At the edges the porous cells are replaced by longitudinally elongated wavy-walled cells.

In internal structure the empty glume is much like that of maize, the transition of *stone cells* to thin-walled *parenchyma* on the inner side distinguishing it from the rachis.

Flowering Glumes and Palets.—The *outer epiderm* of the thin envelopes of both the fertile and the sterile flowers consists of longitudinally elongated cells with thin wavy walls, alternating with hair scars or *hairs* both unicellular and jointed, sometimes with a crescent cell adjoining. An *inner epiderm* of straight-walled cells may or may not be evident.

Pericarp.—The tissues are thin and show little detail in cross section. The *outer epiderm* is more like that of the sorghums than of maize, the elongated cells having thin wavy walls. *Hypoderm* cells are not well developed or absent. The numerous *cross cells*, as in sorghums, are mostly vermiform, transversely arranged and in loose contact, and do not as in maize form an irregular spongy parenchyma. *Tube cells* occur in considerable numbers.

Spermoderm and Perisperm.—Inconspicuous or absent.

Endosperm.—The *aleurone cells* range up to 60 μ in diameter as seen in surface view. Most of the *starch grains* are polygonal, up to 20 μ or more in diameter, closely packed in the horny tissue. Rounded grains occur sparingly. Particularly noteworthy are the minute *aleurone grains* in the protein network about the starch grains. These are commonly evident without treatment with reagents.

Chief Structural Characters.—Rachis, enveloping chaff and kernel, breaking into triangular or trapezoidal pieces, unlike corn cob, with two epiderms and no pith.

In microscopic structure, chaff similar to that of maize, kernel to that of sorghum. Aleurone grains in network about starch grains.

CHEMICAL COMPOSITION.—Jones, Gersdorff, and Moeller [1] found in teosinte protein 1.02 per cent of cystine but no tryptophane.

COIX (JOB'S TEARS)

Coix Lacryma-Jobi L. = *C. arundinacea* Lamk. = *Lithagrostis Lacryma-Jobi* Goertn.

Fr. Larme de Job. Sp. Lágrimas de Job. It. Coire. Ger. Thränengras.

This species, one of a small genus indigenous to the East Indies, yields a remarkable fruit which, like jequirity seeds, is best known as a substitute for beads in necklaces. Aside from any superstition as to the efficacy of such necklaces in warding off disease, the fruit is used in the Orient as an internal drug and also in various regions as a food.

MACROSCOPIC STRUCTURE.—Although the plant itself and the staminate spikelets suggest the close relationship to maize, the kernel

[1] J. Biol. Chem. 1924, **62**, 183.

and chaff completely enclosed in a hard shell are quite unlike the kernel of maize or any other cereal or common grass. The curious round or ovate *shell* is believed to be developed from the leaf sheath. It is silicified, and although only 1 to 3 mm. thick, defies cutting with a knife. In color it is light blue-gray with a porcelain-like luster. On cracking, the inner surface is seen to be lustrous but of a brown color. The peduncle of the staminate inflorescence arises from the tip of the shell.

Enclosed in the shell are the chaff and the kernel. The *chaff* consists of two thin envelopes, one, the thicker and broader of the two, being several-nerved, completely surrounding the kernel. This may be the flowering glume, although the presence of two keels and two narrow wings suggests a palet. In addition there are two narrow more or less involute scales, believed by Mitlacher to belong to the sterile flower. The caryopsis or *kernel* is brown, about as broad as long, and ends in a short point. On the ventral side over the germ is a broad *groove*.

MICROSCOPIC STRUCTURE.—Mitlacher [1] has made a careful study of the microscopic structure of shell, chaff, and kernel.

Shell.—A fine saw may be used to cut the shell in half, holding the specimen in a vise. Owing to the deposited silica, the shell cuts more like marble than like a vegetable product. Under a lens the cross section shows a thin outer pure white tissue; beneath this, small spots, and further inward large spots, both in a yellow ground tissue. Microscopic examination of cross and longitudinal sections cut with a razor shows the small spots to be fibro-vascular bundles and the large spots fiber bundles. Both kinds of bundles are longitudinally arranged and in a ground tissue of stone cells with yellow walls and dark contents which, as seen in cross section, are more or less elongated and are arranged in curves concentric with the fiber bundles much as in kinghead and, in the inner layers, transversely.

Both the *outer* and *inner epiderm* are incrusted with silica, obscuring their study in surface view.

Chaff.—The thin membranous envelopes are much like the thin chaff of maize. Elongated cells with thin, deeply wavy walls, interspersed with twin cells, form the *outer epiderm*. Hairs, which are abundant in maize, are lacking.

A *hypoderm* of thin-walled fibers occurs in the thicker parts.

Pericarp.—The elongated wavy-walled *epicarp* cells often contain a dark brown substance. In form they are like the epicarp cells of the sorghums. A *hypoderm* is lacking or if present in parts is inconspicuous in comparison with the dense hypoderm of maize. *Cross cells* are abun-

[1] Z. allg. oesterr. Apoth.-Ver. 1901, 813, 831, 856, 875, 899, 928.

dant and are of the maize type with branching arms. *Tube cells* are numerous.

Spermoderm and **Perisperm,** as in maize, if present, show no cell structure in cross or surface preparation.

Endosperm.—The *starch grains* are of the maize type but smaller. Mitlacher gives 22 μ as the maximum. They correspond closely with the starch of common and German millet and the foxtails.

Chief Structural Characters.—Chaff and kernel enclosed in siliceous shell.

Thin chaff with longitudinally elongated, wavy-walled cells like those of maize but no hairs. Epicarp with elongated wavy-walled cells and inconspicuous hypoderm suggests sorghum; cross cells branching, of maize type. Starch grains as in maize and sorghum but smaller.

CHEMICAL COMPOSITION.—Analyses of the shelled grain by Church [1] and Yoshimura and Sagara,[2] and of the meal free from bran by Hattori and Komatsu,[3] follow:

Composition of Decorticated Coix

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Church	13.2	18.7	5.2	59.3	1.5	2.1
Yoshimura and Sagara	8.49	17.58	7.15	62.41	2.04	2.33
Hattori and Komatsu	11.92	18.58	3.58	53.61	7.59	4.72

Proteins.—Determination of the nitrogen distribution in the decorticated seed by Yoshimura and Sagara [4] yielded:

	%
Nitrogen soluble in water	0.404
Nitrogen precipitated from last by cupric hydroxide	0.168
Nitrogen insoluble in 10 per cent salt solution	0.539
Nitrogen soluble in 70 per cent alcohol	1.819
Nitrogen soluble in 0.2 per cent sodium hydroxide	2.155
Nitrogen insoluble in 70 per cent alcohol, soluble in 0.2 per cent sodium hydroxide	0.336

From the alcohol extract they prepared a prolamine to which they assigned the name *coicin.*

[1] Watt's Dict. Econ. Prod. India, Calcutta, 1889, **2,** 498.

[2] J. Tokyo Chem. Soc. 1919, **40,** 483.

[3] J. Biochem. (Japan), 1922, **1,** 365.

[4] Loc. cit.

The *Ultimate Composition* of coicin, as determined by Hattori and Komatsu [1] is as follows:

	%
Carbon	52.63
Hydrogen	6.75
Nitrogen	16.61
Sulphur	1.12
Oxygen	22.89
	100.00

Amino Acids of Coicin.—The percentages obtained by Yoshimura and Sagara [2] and Hattori and Komatsu [3] appear in the following table:

Amino Acids of Coicin

	Yoshimura and Sagara	Hattori and Komatsu
	%	%
Alanine	0.50	
Valine	4.30	
Leucine	21.10	4.10
Aspartic acid	0.20	
Glutamic acid	15.00	20.65
Tyrosine	3.30	1.46
Phenylalanine	1.20	
Proline	2.00	
Tryptophane	trace	
Arginine	1.70	0.20
Lysine	.....	0.76
Histidine	0.15	1.88
Ammonia	3.38	
	52.83	29.05

Yoshimura and Sagara, on the basis of their leucine and glutamic acid results, conclude that coicin is similar to gliadin; Hattori and Komatsu, however, on the basis of their figures, notice resemblance to the prolamine of oats.

Nitrogen Distribution, following the method of Osborne and Harris, as obtained by Hattori and Komatsu [4] follows: ammonia nitrogen

[1] J. Biochem. (Japan), **1**, 365.
[2] Loc. cit.
[3] Loc. cit.
[4] Loc. cit.

19.82, humin nitrogen trace, basic nitrogen 4.44, non-basic nitrogen 1.39, amino nitrogen 41.54, and mono-amino nitrogen 32.81 per cent.

Mineral Constituents.—The composition of the ash by Yoshimura and Sagara,[1] recalculated to percentages of the ash, follows:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl	CO_2
%	%	%	%	%	%	%	%	%	%
20.2	2.5	5.2	21.8	3.2	43.2	1.5	2.3	0.1	trace

BROOM CORN

Andropogon Sorghum (L.) Brot. var. *technicus* Körn = *Sorghum vulgare* Pers.

Fr. Houque. Sp. Millo de escoba. It. Sorgo. Ger. Besenhirse.

Under the term "Sorghums" are included several varieties of the genus *Andropogon* formerly assigned specific names under the genus *Sorghum* Pers., some yielding chaffy, others naked, fruits. Although their origin is clouded in obscurity, Africa is probably the original habitat.

FIG. 50.—Broom Corn. Kernel with chaff. *r* two staminate spikelets; g_1 lower empty glume; g_2 upper empty glume; g_3 glume of rudimentary flower; *gf* flowering glume with awn; *p* palet; *c* kernel (caryopsis). ×1. (A.L.W.)

Broom corn is valuable both for its brush and its grain, although the grain is not fully ripe when the brush is in its best condition for technical use. Its culture in the United States is carried out in Illinois and other states of the Middle West, which are also noted for their production of its relative maize, and in California. In the Old World it is grown in the Mediterranean region and the Orient.

MACROSCOPIC STRUCTURE.—The inflorescence is in panicles suggesting the terminal male panicles of maize. At each joint of the rachis are borne three spikelets (Fig. 50), one fertile and two staminate (*r*), on hairy stems. The former is two-flowered, but one flower is rudimentary (g_3). The hard, stiff, yellow or red-brown *empty glumes* (g_1, g_2), 4 to 6 mm. long, closely envelop the *flowering glume* (*gf*) and

[1] J. Biochem. (Japan), **1**, 365.

palet (*p*) of the fertile flower, the *flowering glume* (g_3) of the rudimentary flower, all membranous, and the *fruit* (*c*).

All the *chaff* elements are hairy, although most of those on the outer side of the empty glumes, as well as the upwardly barbed awn 5 to 7 mm. long, become detached in threshing, and as a consequence the chaffy grain is smooth and lustrous. The *grain* or caryopsis is brown, about 5 mm. long and half as broad, blunt-pointed at both ends. The *embryo* extends from the base to about the middle of the side facing the flowering glume.

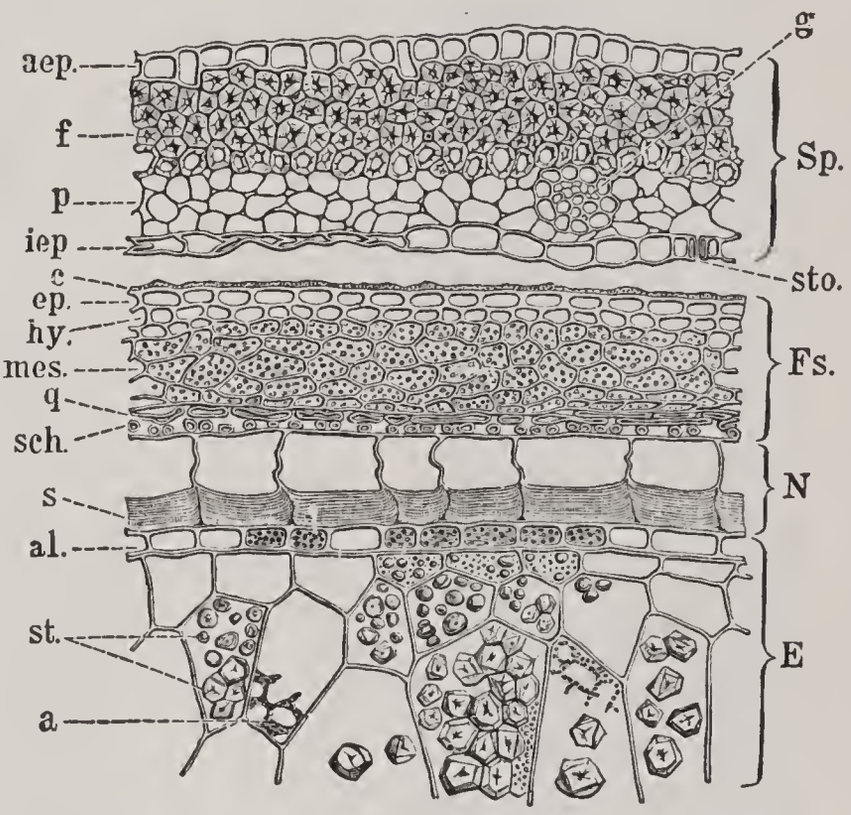


FIG. 51.—Broom Corn. Empty glume and kernel in cross seetion. *Sp* empty glume: *aep* outer epiderm, *f* fiber layer, *p* spongy parenchyma with *g* bundle, *iep* inner epiderm with *sto* stoma. *Fs* pericarp: *ep* epicarp with *c* cutiele, *hy* hypoderm, *mes* starchy mcsocarp, *q* cross cells, *sch* tube cells. *N* perisperm with *s* swollen inner walls. *E* endosperm: *al* aleurone layer, *st* starch grains, *a* protein network. ×160. (A.L.W.)

MICROSCOPIC STRUCTURE. — Harz,[1] Hassack,[2] Mitlacher,[3] and Winton[4] have studied not only broom corn but the other species and varieties of sorghum used as food.

Empty Glumes (Fig. 51, *Sp*; Figs. 52 and 53).—As stated above, these at maturity have almost invariably lost the hairs which clothe the outer epiderm. These hairs often reach 1 mm. in length, are broadest in the middle, tapering toward both ends, and have a lumen much broader than the walls.

Four layers, as is usual, of stiff chaff elements are present: (1) *outer epiderm* (Figs. 51 and 52, *aep*) of wavy-walled long cells and twin cells, (2) *sclerenchyma fibers* (*f*), (3) *spongy parenchyma* (Figs. 51 and 53, *p*) with rectangular cells much as in barley, and (4) *inner epiderm* (*iep*) of elongated, straight-walled cells with stomata (*sto*) and pointed hairs (*h*) with broad lumen.

[1] Samenkunde, p. 1249.

[2] Mitth. Lab. Waarenk. Wiener Handels-Akad. 1887, p. 113.

[3] Z. allg. oesterr. Apoth.-Ver. 1901, 813, 831, 856, 875, 899, 928.

[4] Z. Unters. Nahr.-Genussm. 1903, **6**, 337; Connecticut Agr. Exp. Sta. Rep. 1902, p. 326.

Flowering Glumes and Palet (Fig. 54).—The two envelopes of the fertile fruit, as well as the one of the abortive flower, are thin, membranous and of practically the same structure. Only two layers are present in most parts: (1) *outer epiderm* (*aep*) of thin, wavy-walled long cells interspersed with pointed unicellular (*h*) and blunt jointed (h^1) hairs and round cells or hair scars, and (2) an *inner epiderm* of straight-walled long cells without hairs.

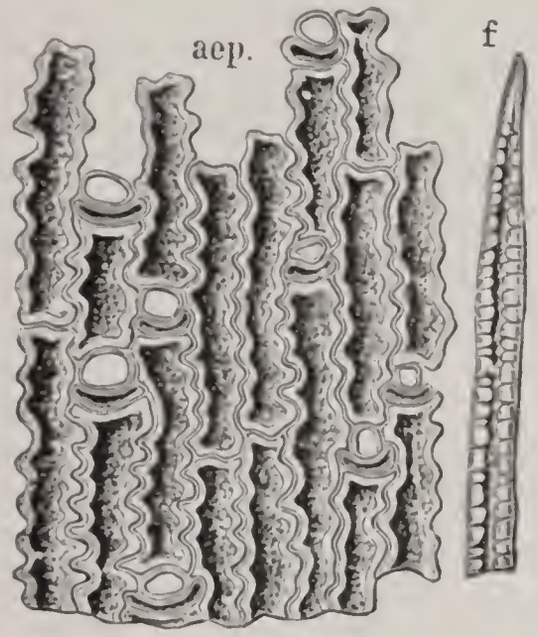


Fig. 52.

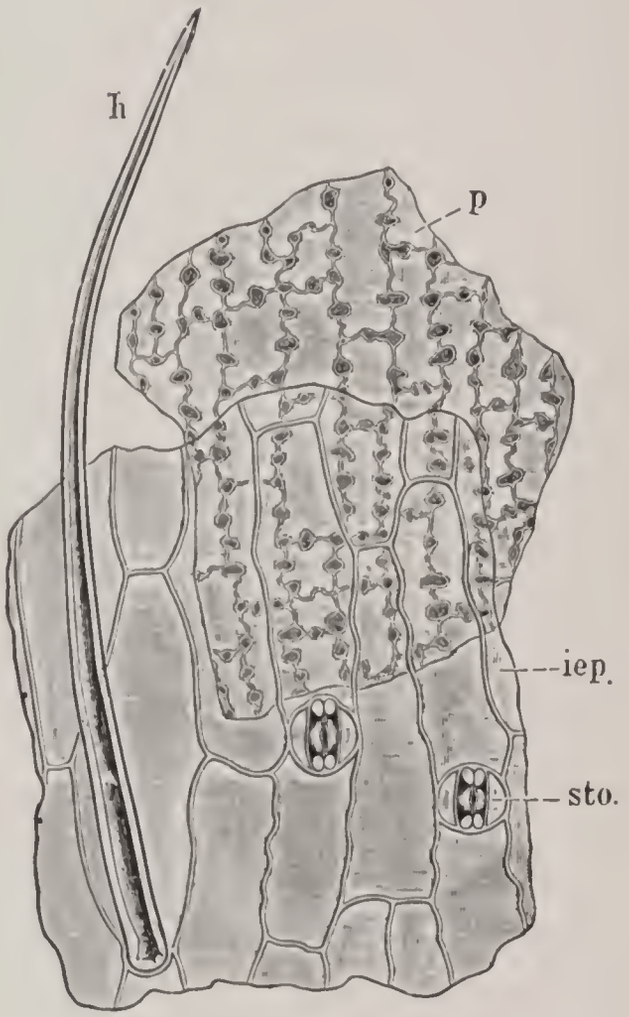


Fig. 53.

Fig. 52.—Broom Corn. Outer layers of empty glume in surface view. *aep* outer epiderm; *f* fiber. ×300. (A.L.W.)

Fig. 53.—Broom Corn. Inner layers of empty glume in surface view. *iep* inner epiderm with *sto* stoma and *h* hair; *p* spongy parenchyma. ×300. (A.L.W.)

Pericarp (Fig. 51, *Fs*; Fig. 55).—Five layers are present: (1) *epicarp* (*ep*) of long cells with thick, pitted, wavy walls, covered by a cuticle (*c*), (2) *hypoderm* (*hy*), one to three cells thick similar to the epicarp but with narrower and thinner walls, (3) true *mesocarp* (*mes*) of round parenchyma cells containing starch grains up to about 6 μ, (4) *cross cells* (*q*) of irregular tubular form, and (5) numerous *tube cells* (*sch*).

The *cuticle*, as first noted by Hassack, is irregular in thickness, owing to a deposit of minute crystals.

Of special interest is the occurrence of *starch grains* in the mesocarp

as first brought out by Harz. These appear in the early stages and persist nearly or quite to maturity, being accompanied at full maturity by chlorophyl grains. They would appear to be direct products of assimilation. Their presence is not, however, a definite varietal peculiarity, although some varieties may retain the starch grains more tenaciously than others, but is dependent on ripeness or other conditions. By scraping and observation with the naked eye the presence or absence of starch may be ascertained.

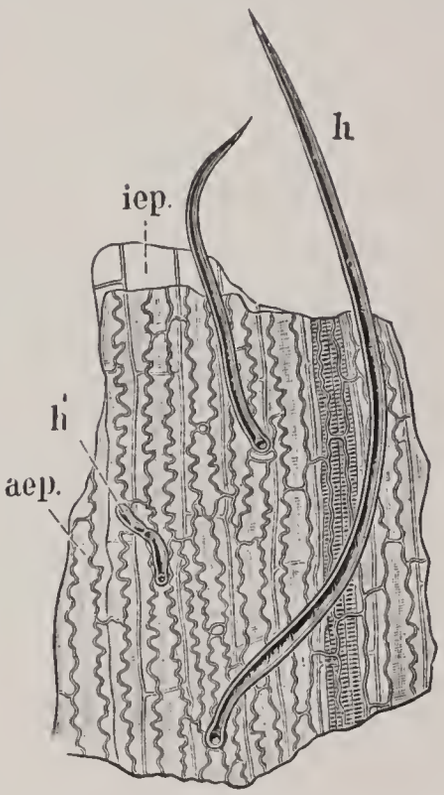


FIG. 54.—Broom Corn. Glume (Fig. 50 g_3) of rudimentary flower in surface view. *aep* outer epiderm with *h* one-celled hair and h^1 two-celled hair; *iep* inner epiderm. ×300. (A.L.W.)

Spermoderm.—No traces are evident.

Perisperm (Figs. 51 and 55, *N*).—In striking contrast to all the common cereals described on the preceding pages, this layer is the most conspicuous of all the bran elements in both cross section and surface view. The radial walls reach 50 μ in height. Both radial and outer walls are thin; the inner wall, on the other hand, is much swollen and very conspicuous in cross section. Their yellow and brown color makes the cells conspicuous in surface mounts.

Endosperm (Fig. 51, *E*; Fig. 55).—Although in surface view the

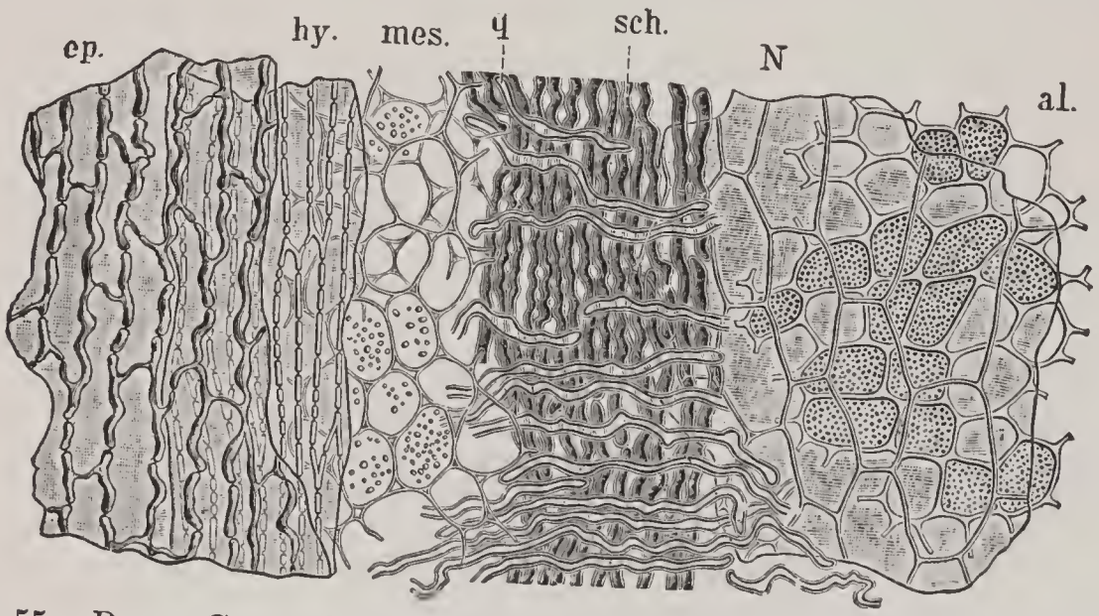


FIG. 55.—Broom Corn. Bran layers in surface view. *ep* epicarp; *hy* hypoderm; *mes* starchy mesocarp; *q* cross cells; *sch* tube cells; *N* perisperm; *al* aleurone cells. ×160. (A.L.W.)

outer aleurone cells are like those of maize, cross sections bring out the fact that there is no sharp demarcation between *aleurone cells* (*al*) and

starch cells. Although in most cereals these two types of cells are well differentiated both as to form and contents, in broom corn, as well as other sorghums, the outer thin-walled cells often approach the aleurone cells, starch being entirely replaced by contents that stain yellow with iodine. In some of the cells further inward the starch grains are enmeshed in a protein network (*a*), the minute threads of which contain granules.

The polygonal starch grains (*st*) of the inner endosperm are practically indistinguishable from those of maize. Meyer observed that the starch grains become reddish instead of blue with iodine solution, but Mitlacher finds, however, that this distinction applies only after soaking the kernels in water, and the writers find it valueless in diagnosis. The grains are usually polygonal with a distinct hilum and often radiating fissures. As in maize starch the maximum size is about 30 μ.

Chief Structural Characters.—Grain chaffy, 4 to 6 mm. long, with glossy brown, empty glumes.

Aleurone cells and starch grains of maize type but in cross section no sharp demarcation. Distinctions from maize: (1) outer epiderm of empty glumes with long cells and small hair scars (maize short, porous and non-porous-walled cells), (2) outer epiderm cells of the thin chaff longer and narrower, (3) hypoderm of the naked kernel not strongly developed, (4) starch often present in mesocarp, and (5) perisperm highly developed with swollen walls.

MICROSCOPY OF BROOM CORN PRODUCTS.—Being used only whole or simply ground for poultry or cattle feed reduces the diagnostic problems to establishing the identity of the whole grains or of a ground material containing all the histological elements. The starch at a glance could be mistaken for only one cereal outside the sorghum group, namely, maize. The distinctions between the two, based on tissues, are noted above under Chief Structural Characters.

If the grain is immature, the tissues may be somewhat other than described, some, as for example the mesocarp, being even more characteristic than in the mature grain.

CHEMICAL COMPOSITION.—See Kaffir Corn.

SUGAR SORGHUM

Andropogon Sorghum (L.) Brot. var. *saccharatus* Körn.

Fr. Sorgho. Sp. Sorgo. It. Sorgo. Ger. Zuckerhirse.

All sorghums, as well as maize, contain sugar in the juice of the stalk, but in sugar sorghum this has been further increased by selection not

only in the Orient and Africa, where it has long been cultivated, but also in the United States, where in the latter half of the nineteenth century and before the sugar beet came into prominence it gave promise of being an important source of commercial sugar.

Similar to broom corn, if cut before maturity, in this case for sugar or syrup manufacture, the grain is of inferior value for feeding.

MACROSCOPIC STRUCTURE.—The varieties commonly grown, including Early Amber and Early Orange, closely resemble broom corn except that the brush is not so well developed and the *empty glumes* are somewhat broader, of a black or dark color, and do not so closely invest the *kernel*, although they usually are not loose enough to permit separation to any great extent by threshing.

MICROSCOPIC STRUCTURE.—No histological differences from broom corn have been noted, except the presence of the dark pigment in the *outer epiderm* of the empty glumes.

CHIEF STRUCTURAL CHARACTERS.—Similar to broom corn but usually darker.

CHEMICAL COMPOSITION.—See Kaffir Corn.

KAFFIR CORN

Andropogon Sorghum (L.) Brot.

Fr. Mil d'Afrique. It. Panino. Ger. Kaffernhirse.

As the name indicates, this is an African cereal. It is used in Africa as a bread cereal and a cattle food. It is grown to some extent in the United States and is especially prized as a poultry food.

In habit of growth it is distinguished from durrha and milo maize by the erect head, but like them the kernel is removed from the chaff by threshing.

Feterita is similar to kaffir corn but earlier and more drought-resistant.

MACROSCOPIC STRUCTURE.—There are two common varieties, the white and the red, differing in the color of the naked kernel. The *empty glumes* are somewhat shorter than the fruit and awns are absent. The *kernel* (caryopsis) is nearly globular, about 4 mm. long.

MICROSCOPIC STRUCTURE.—The distinctions from broom corn and sugar sorghum are (1) the *perisperm* is not evident and (2) the *hypoderm* is more robust, consisting often of thick-walled cells three deep on the kernel.

CHIEF STRUCTURAL CHARACTERS.—Kernel white or red, naked, nearly globular.

Hypoderm of thick-walled cells, three deep. Perisperm not evident. Otherwise similar to broom corn and sugar sorghum.

CHEMICAL COMPOSITION.—For comparison, analyses of the different varieties of sorghum are given in this section. Studies of the protein and fat have largely been confined to kaffir corn, but the results doubtless apply to other members of the group. The chaffy sorghums, broom corn and sugar sorghum, contain somewhat more fiber than the naked varieties.

Proximate analyses reported by Chamberlain,[1] Ball and Rothgeb,[2] and Winton [3] illustrate the differences in composition of the different varieties.

Composition of Varieties of Sorghum (Chamberlain)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Edra	10.91	11.44	4.34	80.31	1.73	2.18
Gidjep-jowar	11.02	10.13	3.30	83.36	1.57	1.64
Daydi-jowar	11.35	8.87	2.41	85.31	1.66	1.75
Natal	10.91	14.50	2.97	78.99	1.94	1.60
Djuggara	11.35	13.81	3.52	79.96	1.66	2.04
White milo maize	12.80	11.12	2.65	82.44	2.12	1.67
White kaffir corn	12.10	12.94	2.82	79.95	2.32	1.97
White kaffir corn	12.55	11.56	3.33	81.68	1.78	1.65
Red kaffir corn	12.31	10.06	3.73	83.13	1.56	1.51
Dwarf milo maize	11.84	12.69	3.41	80.71	1.65	1.54

Composition of Varieties of Sorghum (Ball and Rothgeb)

	Samples	Water	Protein	Fat	N-f.ext.	Fiber	Ash
	%	%	%	%	%	%	%
Milo maize	67	9.32	12.54	3.15	71.89	1.48	1.62
Dwarf milo maize	55	9.38	12.16	3.27	72.09	1.47	1.63
Feterita	8	9.58	14.00	2.90	70.32	1.48	1.72
Blackhull kaffir corn	78	9.58	14.10	3.47	69.49	1.58	1.78
Dwarf blackhull kaffir corn	13	9.95	13.09	3.25	70.49	1.52	1.70
Red kaffir corn	37	9.56	12.01	3.16	72.03	1.51	1.73
Shallu	10	10.38	15.17	3.69	66.86	1.92	1.98

[1] U. S. Dept. Agr., Bur. Chem. 1909, Bul. 120.

[2] U. S. Dept. Agr., 1915, Farm. Bul. 686.

[3] Connecticut Agr. Exp. Sta. Rep. 1902, p. 326.

Composition of Varieites of Sorghum (Winton)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Broom corn:						
Long Brush Evergreen *	12.63	10.19	3.49	67.90	2.83	2.46
Early Japan *	12.32	11.87	3.52	65.56	3.84	2.89
California Golden *	12.86	10.44	3.74	65.54	3.84	3.28
Improved Dwarf *	12.88	9.56	3.20	64.93	6.19	3.24
Sugar sorghum:						
Early Amber *	12.37	11.12	3.74	67.43	3.08	2.26
Early Orange *	13.00	9.81	3.65	69.80	1.99	1.75
White kaffir corn †	12.66	10.31	3.30	71.01	1.44	1.28
Red kaffir corn †	12.23	10.62	3.44	71.42	1.10	1.19
White durrha †	12.20	12.62	3.95	67.63	1.53	2.07
Brown durrha †	12.48	12.25	3.97	68.45	1.19	1.66
White milo maize †	11.98	11.19	3.17	70.92	1.37	1.37
Yellow milo maize †	11.18	10.31	2.91	72.08	1.75	1.77

* With chaff. † Without chaff.

The summary of 5 analyses of kaffir corn by Baird and Francis [1] which follows should be considered in connection with the determinations of the individual carbohydrates given under that head:

Composition of Kaffir Corn (Baird and Francis)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	11.26	11.37	3.46	65.33	1.88	1.20
Max.	13.45	12.85	3.80	70.83	2.90	1.67
Aver.	**12.36**	**12.11**	**3.63**	**68.08**	**2.39**	**1.43**

Proteins.—The principal protein of kaffir corn and doubtless of allied if not all varieties of the species is *kafirin*, a prolamine, first isolated by Johns and Brewster,[2] constituting more than half of the protein of the grain. It is similar in ultimate composition to zein but differs in its decomposition products and certain physical characters. From a 70 per cent alcohol solution, in which it is less soluble than zein, it readily coagulates on overheating.

[1] J. Ind. Eng. Chem. 1910, **2**, 531.
[2] J. Biol. Chem. 1916, **28**, 59.

The *Ultimate Composition* of kafirin, as obtained by Johns and Brewster, is as follows:

	%
Carbon	55.19
Hydrogen	7.36
Nitrogen	16.44
Sulphur	0.60
Oxygen	20.41
	100.00

Amino Acids of Kafirin.—Hydrolysis by Jones and Johns [1] yielded the following: glycocoll none, alanine 8.08, valine 4.26, leucine 15.44, cystine 0.84, aspartic acid 2.27, glutamic acid 21.23, tyrosine 5.49, phenylalanine 2.34, proline 7.8, tryptophane present, arginine 1.59, lysine 0.95, histidine 1.12, and ammonia 3.46 per cent; total 74.87 per cent.

Jones, Gersdorff, and Moeller [2] obtained the following figures in two preparations:

	I	II
	%	%
Cystine	0.55	0.53
Tryptophane	1.17	0.73

Nitrogen Distribution in Kaffir Protein.—Dowell and Menaul [3] obtained practically all the protein matter of the grain by extracting with dilute alkali and precipitating with acetic acid. Determinations in this material by Van Slyke's method gave the following results:

	%
Humin N adsorbed by lime	4.40
Hymin N in amyl alcohol extract	
Cystine N	0.96
Arginine N	2.41
Lysine N	1.05
Histidine N	1.78
Amino N of filtrate	74.95
Non-amino N of filtrate	7.20
Amide N	8.46

[1] J. Biol. Chem. 1918, **36**, 323.
[2] Ibid. 1924, **62**, 183.
[3] Ibid. 1921, **46**, 437.

Fat.—Equal quantities of 5 lots of kaffir corn were ground by Baird and Francis [1] to a fine powder and digested a day each, at room temperature, with five successive portions of gasoline. The filtered liquid was evaporated and the residue dried at 100° in a current of dry carbon dioxide. The fat was semi-liquid, greenish yellow, and agreeable to the taste.

Seven years later in the same laboratory and by practically the same method Francis and Friedemann [2] prepared ether extracts of kaffir corn, feterita, and milo maize. In the case of kaffir corn and feterita the extract was a grease of the consistency of vaseline; in the case of milo maize it was liquid with a small amount of solid fats.

Physical and Chemical Values.—The values of kaffir corn oil in the following table are by Baird and Francis, excepting those for refractive index (temperature not given), saponification number, and Reichert-Meissl number, which, together with all values of feterita and milo maize oils, are by Francis and Friedemann:

Kind of oil	Sp. gr. 15° C.	Ref. ind.	Melt. point	Maumené No.	Sapon. No.	Iodine No.	Reich.-Meisl No.	Hehner No.	Acetyl No.	Fatty acids, titer	Unsap. matter
			° C.							° C.	%
Kaffir.....	0.9398	1.4669	44.2	68.1	193.6	109.7	4.3	93.2*	42.3	34.0	1.72
Feterita...	0.9260	1.4651	44.7	....	187.3	....	3.0	95.1	26.8	30.6	0.84
Milo.....	0.9275	1.4675	42.9	....	189.5	....	1.3	91.6	20.4	29.7	0.05

* Soluble acids 0.66, liquid acids 85.98, solid acids 7.48, and free fatty acids 27.02 per cent.

In most respects the fats of the three sorghums agree closely in their characteristics with each other. They have higher melting points than maize oil.

Composition.—Francis and Friedemann note that all three fats contain six fatty acids in about the same proportion. The total volatile acids ranged from 0.59 to 0.85 per cent and consisted of *formic* and *butyric acids*. From 7 to 10 per cent was saturated acids, *stearic* and *palmitic*, together in the case of kaffir and milo maize oil with traces of higher acids. Stearic predominated in kaffir and feterita, palmitic in milo maize oil. From 80 to 86 per cent consisted of the unsaturated acids, *oleic* and *linolic*.

Carbohydrates.—An instructive series of determinations by Baird and Francis [3] of the carbohydrates of kaffir corn is summarized

[1] Loc. cit.

[2] Oklahoma Agr. Exp. Sta. 1917, Bul. **117.**

[3] Loc. cit.

below. A summary of the usual proximate analyses is given on a preceding page.

CARBOHYDRATES OF KAFFIR CORN (BAIRD AND FRANCIS)

	Starch	Pentosans	Galactans	Glucose	Sucrose	N-f. ext.
	%	%	%	%	%	%
Min.	57.12	3.79	0.10	1.34	0.27	66.16
Max.	60.71	5.04	0.24	1.44	0.80	68.44
Average	58.86	4.33	0.15	1.38	0.53	67.33

Acid.—*Hydrocyanic acid* is formed in the sorghum plant during growth through the agency of a glucoside, *dhurrin.*[1]

Dowell[2] found that sorghum cut after a drought contained 0.0514 per cent of hydrocyanic acid, whereas that grown under normal conditions contained only 0.0220 per cent.

Enzymes.—The amylase of cholam (*Sorghum vulgare*) has been studied and compared with that of sprouted barley by Patwardhan and Norris [3] and by Narayanamurti and Norris.[4] Cholam amylase is more active in its liquefying power than barley amylase, but the reverse is true of its saccharifying power, hence it is believed that the enzymes are not the same in the two grains. Results on the saccharifying power of electrodialyzed and dialyzed extracts indicated that a partial separation of liquefying and saccharifying enzymes was effected.

Mineral Constituents.—Ash analyses of 4 samples of kaffir corn by Baird and Francis [5] are summarized as follows:

	K_2O	NaO_2	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl	C	Sand
	%	%	%	%	%	%	%	%	%	%	%
Min.	24.82	0.94	1.46	15.25	1.18	37.47	0.17	0.96	0.44	0.17	2.88
Max.	29.78	2.42	2.15	18.86	2.08	46.72	1.22	4.15	0.58	0.31	5.73
Average	27.17	1.18	1.80	17.34	1.57	43.04	0.52	2.16	0.49	0.25	4.06

Minor Mineral Constituents. *Zinc.*—Sorghum (*S. vulgare* Pers.) 13.8 mg. per kilo, dry basis (Bertrand and Benzon).[6]

[1] Bul. Imp. Inst. 1919, **17**, 259.
[2] J. Agr. Res. 1919, **16**, 175.
[3] J. Indian Inst. Sci. 1928, A**11**, 121.
[4] Ibid. p. 134.
[5] Loc. cit.
[6] Bul. soc. hyg. aliment. 1928, **16**, 457.

WHITE MILO MAIZE

Andropogon Sorghum (L.) Brot. var.?

Ger. Weisser Milo-Mais.

White branching sorghum, white African millet, or white milo maize are the names for a variety closely resembling white kaffir corn in gross and minute structure. The head sometimes bends over like durrha.

MICROSCOPIC STRUCTURE.—See Broom Corn.

CHEMICAL COMPOSITION.—See Kaffir Corn.

DURRHA

Andropogon Sorghum (L.) Brot. var. *durra* (Forskal) Hackel.

Ger. Durrha.

Two varieties of durrha are cultivated in the United States, the brown and the white, the latter also known as Jerusalem corn.

MACROSCOPIC STRUCTURE.—In habits of growth, the two are the same, the dense head bending over and forming a goose neck on approaching maturity. The obtuse, densely hairy *empty glumes* in both varieties are about half the length of the kernels, which are usually separated from the chaff on threshing. The *kernels* are the same except for color, being flattened, more or less lenticular, 5 to 6 mm. long and broad.

White durrha differs from the brown in one respect: it is awned.

MICROSCOPIC STRUCTURE.—Under the microscope these two varieties show an important difference: in the brown the *perisperm* is well developed whereas in the white none is evident. In both, the outer layers of the starchy *endosperm* usually contain no starch grains.

Chief Structural Characters.—Grain naked, large, flattened, brown or white.

Perisperm well developed in brown, not evident in white variety. Outer endosperm non-starchy.

CHEMICAL COMPOSITION.—See Kaffir Corn.

YELLOW MILO MAIZE

Andropogon Sorghum (L.) Brot. var. *durra* (Forskal) Hackel.

Ger. Gelber Milo-Mais.

According to Ball and Davy, of the Bureau of Plant Industry, U. S. Department of Agriculture, this cereal probably belongs under the same variety as white durrha or Jerusalem corn.

MACROSCOPIC STRUCTURE.—The *empty glumes* are pubescent, the *flowering glumes* awnless. The *caryopsis* is yellow, somewhat longer (5 to 6 mm.) than the empty and flowering glumes. It is about the same size as the caryopsis of brown durrha but more nearly globular.

MICROSCOPIC STRUCTURE.—The caryopsis agrees in structure with that of white durrha.

CHIEF STRUCTURAL CHARACTERS.—Kernel more nearly globular than that of brown durrha, yellow.

Like white durrha in structure.

CHEMICAL COMPOSITION.—See Kaffir Corn.

GREEN FOXTAIL

Setaria viridis Beauv. = *Chætochloa viridis* (L.) Scribn.

Ger. Borstengras.

Although a weed in field and garden, this species well serves as the type of the *Panicum* group (*Paniceæ*) and is in fact the probable wild form of one of the most valuable cultivated species, *Setaria italica* (German millet), a description of which is given in a following section.

The chaffy fruit of green foxtail occurs in large quantities in wheat of certain regions, notably the northwestern states of the United States.

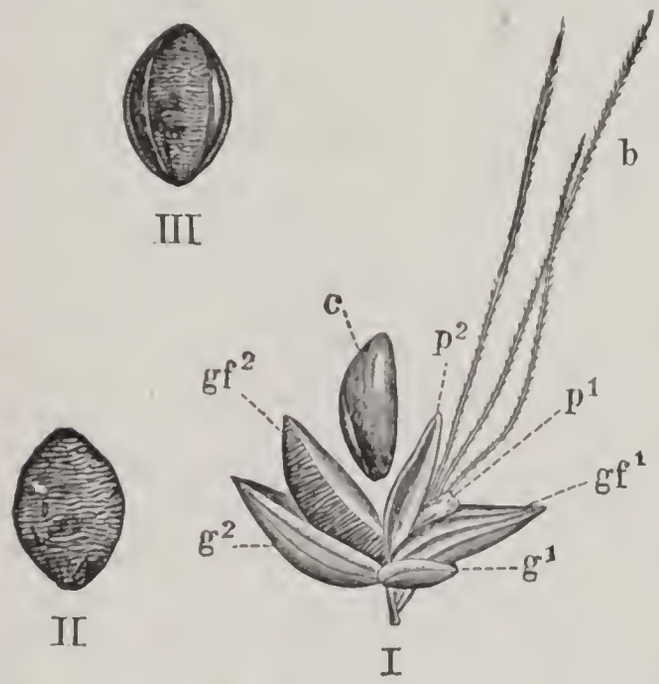


FIG. 56.—Green Foxtail. I spikelet with ripe kernel: g^1 lower empty glume; g^2 upper empty glume; gf^1 glume and p^1 palet of staminate flower; gf^2 glume and p^2 palet of fertile flower; *c* kernel; *b* bristles. II kernel with chaff on dorsal side showing flowering glume. III kernel and chaff on ventral side showing palet. ×8. (A.L.W.)

MACROSCOPIC STRUCTURE (Fig. 56).—The two flowers of the spikelet are subtended by two *empty glumes*, the lower (g^1) being three-nerved and less than 1 mm. long, the upper (g^2) five-nerved and 2 mm. long. One of the flowers is staminate with membranous *flowering glume* (gf^1) and *palet* (p^1), the other perfect with horny *flowering glume* (gf^2) and *palet* (p^2). Both envelopes of the perfect flower have fine transverse wrinkles, evident under a lens, except on the wings of the palets, which are smooth. At maturity they are dark colored and tightly envelop the fruit. Two to four upwardly barbed *bristles* (*b*) rise from the base of the spikelet.

The caryopsis or *kernel* (*c*) is about 2 mm. long. It is flat on the ventral side with a dark-colored spot at the hilum near the base. On the dorsal side, extending from the base to the middle of the fruit, is a depression beneath which is the embryo.

MICROSCOPIC STRUCTURE.—Winton [1] has published detailed descriptions of the chaff and caryopsis on which the following is based.

Thin Glumes and Palet.—Both empty glumes and the flowering

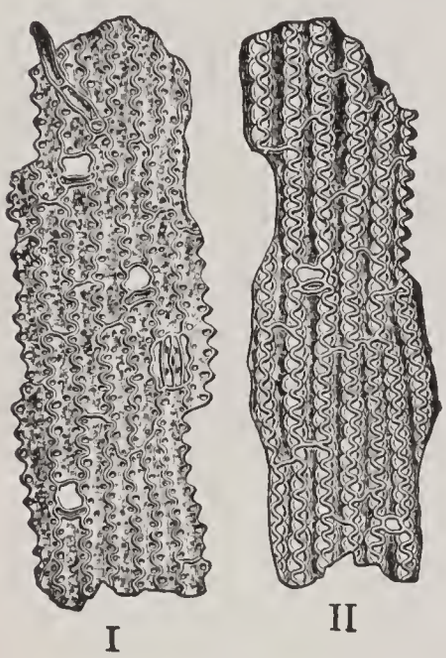


FIG. 57.

FIG. 58.

FIG. 57.—Green Foxtail. Glume of staminate flower in surface view. I outer epiderm at edge, II in middle. ×300. (A.L.W.)

FIG. 58.—Green Foxtail. Palet of fertile flower. Left, outer epiderm of smooth edge; right, of wrinkled middle portion. ×60. (A.L.W.)

glume and palet of the staminate flower have practically the same structure.

Only two layers are in most parts evident: (1) *outer epiderm* (Fig. 57) of elongated wavy-walled cells, interspersed with round cells (or hair scars), twin cells, and near the edges stomata, and (2) *inner epiderm* of elongated cells with thin, straight walls. Under the nerves and at the base a *mesophyl* is present. Pores occur in the walls of the outer epidermal cells, being largest in the middle portion of the glume or palet where they are bordered and fill the bends of the walls.

Thick Glume and Palet (Fig. 58).—In these the normal number of layers is present except in the thin wings of the palet: (1) *outer epiderm*

[1] Z. Unters. Nahr.-Genussm. 1903, **6**, 433; Connecticut Agr. Exp. Sta. Rep. 1902, p. 339.

of thick wavy-walled cells which on flowering glume and middle portion of palet are broad, square or slightly elongated (Fig. 60) but on the wings of the palet are narrow and elongated (Fig. 59), (2) *hypoderm* of

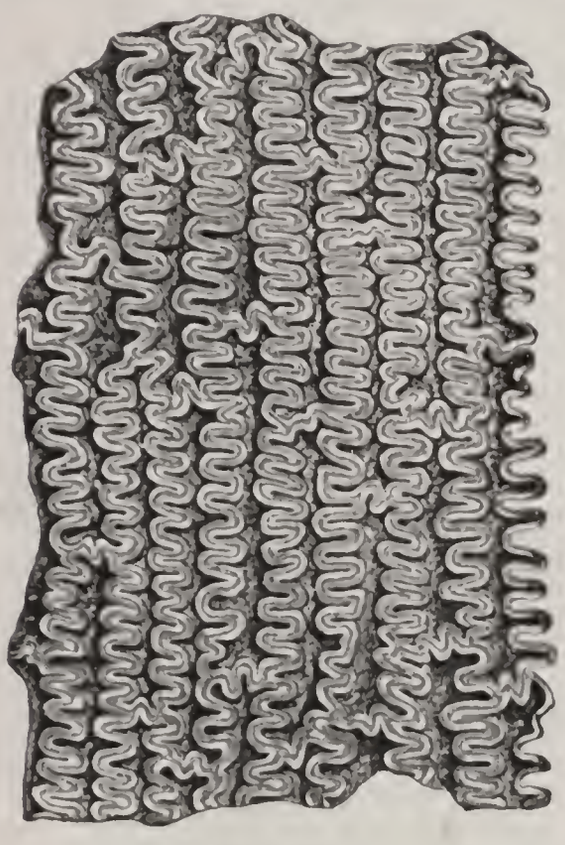


Fig. 59.

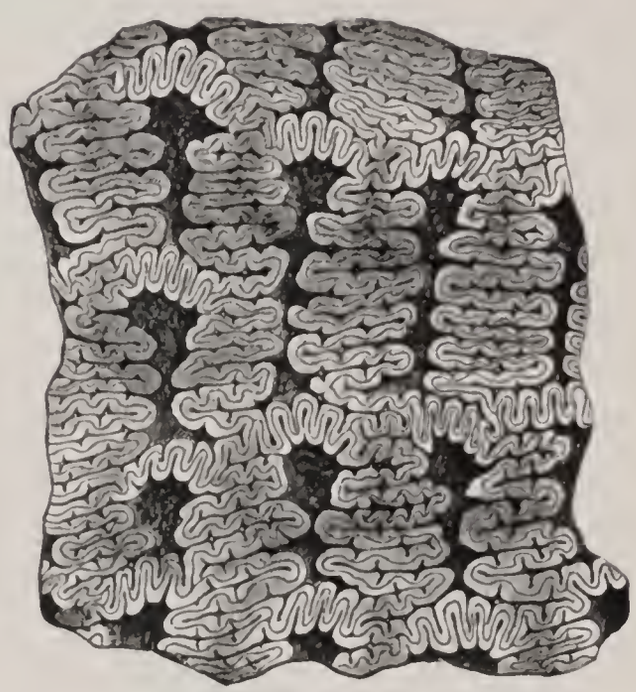


Fig. 60.

Fig. 59.—Green Foxtail. Edge of mature palet of fertile flower in surface view, showing outer epiderm. ×300. (A.L.W.)

Fig. 60.—Green Foxtail. Same .as Fig. 59 but from middle. ×300. (A.L.W.)

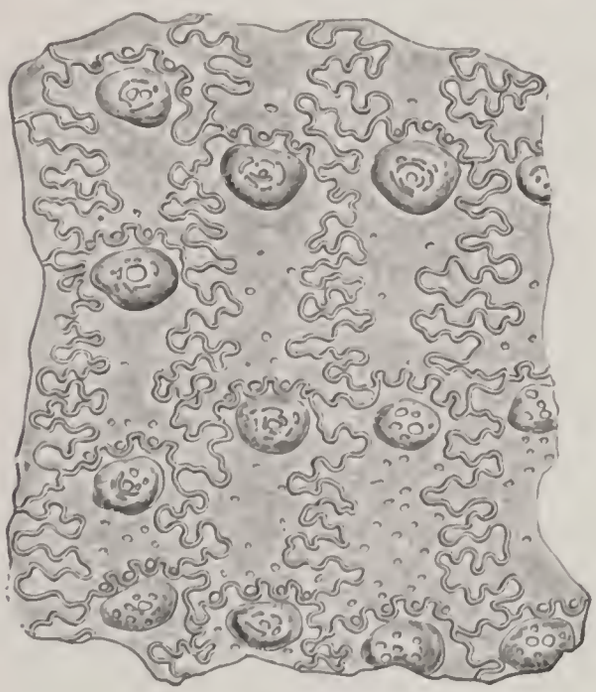


Fig. 61.

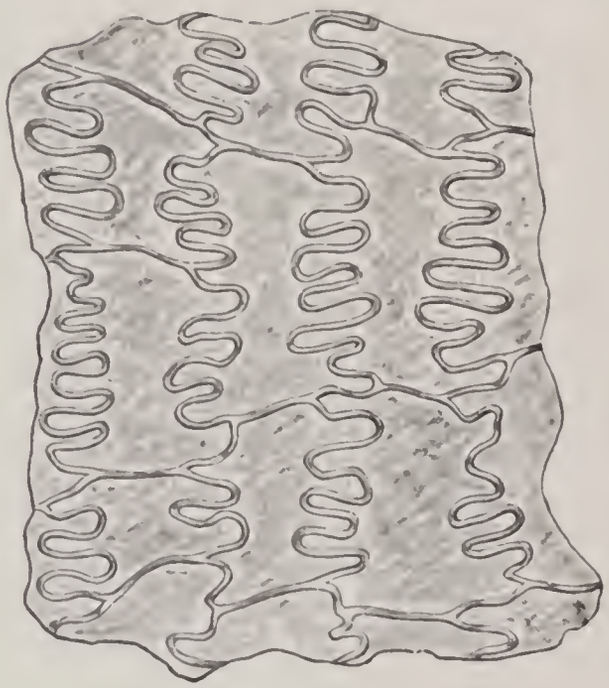


Fig. 62.

Fig. 61.—Green Foxtail. Same as Fig. 60 but immature, surface focus. ×300. (A.L.W.)

Fig. 62.—Green Foxtail. Same as Fig. 60 but immature, deep focus. ×300. (A.L.W.)

thickened fibers, (3) *mesophyl* of parenchyma (not spongy), and (4) an *inner epiderm* of rectangular cells.

The square or slightly elongated cells of the *outer epiderm* are remarkable for the compoundly sinuous walls, the wrinkles with crests at the ends of the cells where the lumen is broadened, and here and there dark contents. In the early stages of growth the side walls near the surface are compoundly sinuous (Fig. 61); adjoining the hypoderm they are simply sinuous (Fig. 62). A wart with pores occurs at the end of the cell, which later has a broadened lumen.

Pericarp (Fig. 63, *F*; and Fig. 64).—After scrapings from the kernel are warmed with 1 per cent sodium hydroxide, acidified with acetic acid, and mounted in chlorzinc iodine, the tissues of the pericarp are

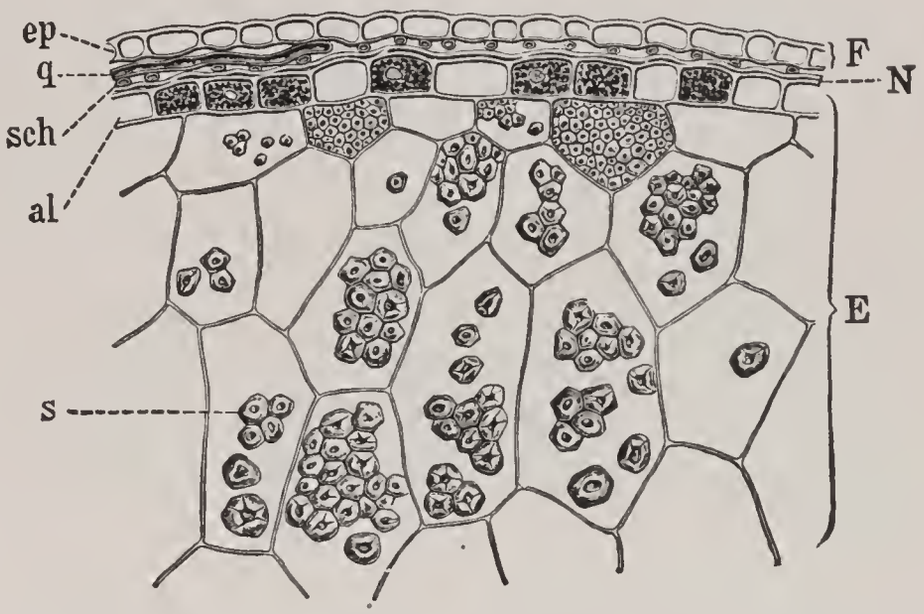


FIG. 63.—Green Foxtail. Kernel in cross section. *F* pericarp: *ep* epicarp, *q* cross cells, *sch* tube cells. *N* perisperm. *E* endosperm: *al* aleurone cells, *s* starch cells. ×300. (A.L.W.)

clearly differentiated from those of the seed by the absence of a decided coloration.

Only three layers are present: (1) *epicarp* (*ep*) consisting of elongated cells with wavy walls except at the hilum where they are straight, (2) *cross cells* (*q*), similar to the tube cells of the next layer but broader and transversely arranged, and (3) narrow *tube cells* (*sch*) 2 to 4 μ wide and up to over 300 μ long.

Spermoderm.—The treatment above described brings out a transparent cuticularized coat stained bright yellow. This undoubtedly belongs to the spermoderm, although as in maize no cell walls are evident.

Perisperm (Figs. 63 and 64, *N*).—After the foregoing treatment a layer of elongated cells with beaded walls is sometimes evident. Vogl,[1]

[1] Wicht. Nahr.-Genussm. Berlin, 1899, p. 135.

who studied German and common millet, considers these cells, as well as the cuticle above described, as belonging to the perisperm.

In cross section this layer is reduced to a colorless line; in surface preparations, on treatment with sodium hydroxide, it is clearly evident, the cells being polygonal with beaded walls.

Endosperm (Fig. 63, *E*; Fig. 64).—The *aleurone cells* (*al*) are rather small, up to 20 μ, of the usual type. The *starch grains* (*s*) of the endosperm are more or less polygonal with a conspicuous hilum. In the outer layers they are small but further inward they reach 18 μ. As brought out by Vogl,[1] the network remaining after dissolving the starch masses in sodium

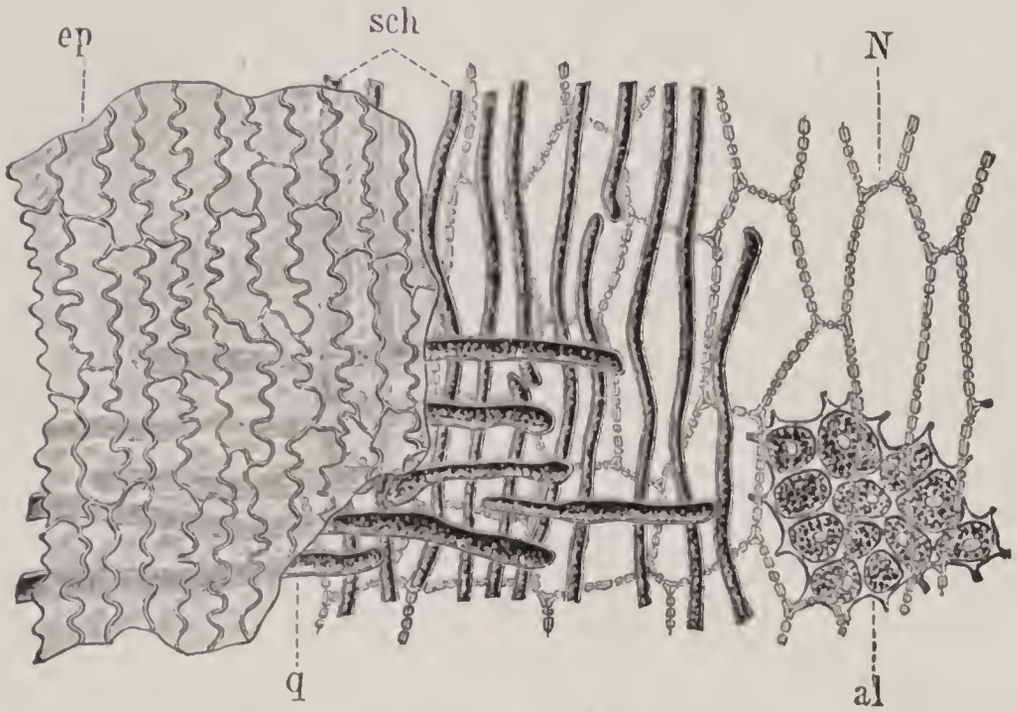


FIG. 64.—Green Foxtail. Bran coats in surface view. *ep* epicarp; *q* cross cells; *sch* tube cells; *N* perisperm; *al* aleurone cells. ×300. (A.L.W.)

hydroxide is beaded as is true of all species of *Setaria* and *Panicum* examined, whereas in buckwheats the residual network is not beaded.

CHIEF STRUCTURAL CHARACTERS.—Kernel 2 mm., invested by transversely wrinkled, dark-colored, thick envelopes (glume and palet).

Outer epiderm of envelopes largely of isodiametric or moderately elongated cells with deeply compoundly sinuous walls and lumen, broadened at end, containing a dark substance. Epicarp of elongated, wavy-walled cells: cross cells and tube cells worm-like. Perisperm cells with beaded walls. Starch grains polygonal, up to 18 μ, with distinct hilum.

CHEMICAL COMPOSITION.—An analysis given by Winton[2] follows:

[1] Loc. cit.

[2] Connecticut Agr. Exp. Sta. Rep., 1902, p. 344.

Water	Protein	Fat	N-f. ext.	Fiber	Ash
% 11.76	% 14.50	% 5.56	% 51.44	% 11.24	% 5.50

YELLOW FOXTAIL

Setaria glauca Beauv. = *Chætochloa glauca* (L.) Scribn.

Fr. Vulpin. Sp. Carricera. It. Coda di volpe. Ger. Gelbe Borstengras.

Yellow foxtail is a troublesome cosmopolitan weed in field and garden. The fruit, however, occurs less often than green foxtail in American grain.

MACROSCOPIC STRUCTURE (Fig. 65).—This species is distinguished from green foxtail by the yellow color of the spike, the larger size of the *fruit* and its enveloping *flowering glume* and *palet*, and the bolder wrinkles on the flowering glume. The *upper empty glume* is little more than half the length of the flowering glume of the fertile flower, whereas in green foxtail it is about the same length.

I II

FIG. 65.—Yellow Foxtail. Grain with chaff. I dorsal side showing flowering glume; II ventral side showing palet and edge of glume. ×8. (A.L.W.)

MICROSCOPIC STRUCTURE.—In histological structure the mature kernel and its envelopes agree with those of green foxtail except as regards the wrinkles on the flowering glume, which are 80 to 120 μ apart, whereas in green foxtail they are but 30 to 60 μ. The wrinkles on the palets of the two species are practically the same.

CHIEF STRUCTURAL CHARACTERS.—Grain larger than that of green foxtail; wrinkles of flowering glume wider apart. Otherwise same as green foxtail.

CHEMICAL COMPOSITION.—An analysis by Winton [1] showed the following:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
% 10.49	% 11.50	% 6.03	% 40.73	% 23.02	% 8.23

[1] Connecticut Agr. Exp. Sta. Rep. 1902, p. 344.

GERMAN MILLET

Setaria italica Beauv. = *S. panis* Jessen.

Fr. Millet de Hongrie. Ger. Kolbenhirse.

Although assigned a separate Latin name, German millet is generally believed to be a cultivated variety of green foxtail. In the United States, where it is grown only for fodder, it is known as millet or Hungarian grass. It should not be confused with true millet (*Panicum miliaceum* L.) Like the latter it has been cultivated since prehistoric times in Europe and Asia.

MACROSCOPIC STRUCTURE.—Hubbard [1] describes several varieties, differing chiefly in the color of the grain (yellowish, reddish, or blackish with yellow markings) and the color and length of the bristles. Unlike that of green foxtail, its kernel separates readily from the chaff.

MICROSCOPIC STRUCTURE.—See Green Foxtail.

CHIEF STRUCTURAL CHARACTERS.—Fruit naked on threshing, variously colored. Otherwise like green foxtail.

COMMON MILLET

Panicum miliaceum L.

Fr. Millet commun. Sp. Mijo. It. Miglio comune. Ger. Rispenhirse.

True or common millet has been cultivated since prehistoric times in Asia, northern Africa, and southern Europe. It was grown by the ancient Egyptians, Lake Dwellers, East Indians, Greeks, and Romans. In China, Japan, India, and parts of Europe it is still cultivated for human food. Under the Russian name "proso" it has been introduced into the United States.

The term "millet," usually with a qualifying word, is applied, often loosely, to several species of *Panicum*, *Setaria* (German millet, Italian millet), and sorghum (Indian millet), as well as to *Eleusine coracana* (African millet) and *Pennisetum typhoideum* (pearl millet). The usage is as various as that of the term "corn," although not like the latter applied to the cereals of first importance to Europeans.

MACROSCOPIC STRUCTURE.—Common millet, as well as other grains of the genus *Panicum*, is readily distinguished from millets of the genus *Setaria* by the smooth, lustrous, hard, and coriaceous *flowering glume* and *palet*. In both genera these are equal to or slightly exceed the length of the *caryopsis*, which in common millet is about 2 mm. long

[1] Am. J. Bot. 1915, **2**, 187.

and nearly 2 mm. broad. The yellow or light buff color of the *chaff* of common as well as German millet distinguishes these from green foxtail with its dark-colored or spotted chaff.

MICROSCOPIC STRUCTURE.–Vogl [1] devotes several pages to detailed descriptions and thirteen cuts to illustrating the structure of common millet. These show few differences from German millet and its wild form, green foxtail, described on the foregoing pages.

Chaff.—Both flowering glume and palet, being smooth, are readily distinguished from the wrinkled chaff of German millet, and by this character, as well as the light color, from green foxtail.

Over most of the surface the *outer epiderm* is made up of isodiametric or moderately elongated cells with compoundly sinuous walls as in green foxtail but without pronounced color or irregularities of surface; on the edges the cells are longer, narrower, and thinner walled.

Pericarp, Spermoderm, and Perisperm.—As in green foxtail.

Endosperm.—The *aleurone cells* are somewhat larger than in the Setarias, being, according to Vogl, 20 to 60 μ in diameter as seen in surface view, but the *starch grains* and the beaded network left on dissolving these in sodium hydroxide are indistinguishable in the two cereals.

Chief Structural Characters.—Same as of green foxtail and German millet except that *outer epiderms* of the flowering glume and palet are smooth, without dark pigment, and the *aleurone cells* are larger.

MICROSCOPY OF COMMON MILLET PRODUCTS.—Millet grits and flour, prepared in the Old World, contain in addition to starch, bran tissues, of which the wavy-walled epicarp and the beaded perisperm are noticeable, germ tissues, and occasional fragments of the chaff. Distinctions from German millet and green foxtail are noted under chief characters above.

CHEMICAL COMPOSITION.—Bersch,[2] in connection with the study of the chaffy grains known collectively in Germany as *Hirse* and including several species of *Setaria* and *Andropogon* (*Sorghum*) as well as *Panicum*, has made an extended study of the milling products of common millet (*Panicum miliaceum*). The decorticated millet suitable for human food is a coarsely granular product which is of considerable importance in old Austro-Hungary. Analyses of the leading products are tabulated on the following page.

A Chinese sample of Huang-mi analyzed by Adolph[3] contained: water 8.49, protein 10.88, fat 3.36, nitrogen-free extract 74.63, fiber 1.02, and ash 1.62 per cent. It is obviously a decorticated product.

[1] Wicht. Nahrungs-u. Genussm. Berlin, 1899, p. 135.
[2] Land. Vers.-Stat. 1895, **46**, 103.
[3] Philippine J. Sci. 1926, **30**, 287.

Composition of Common Millet and Products (Bersch)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Rough millet	9.40	11.56	3.29	62.97	10.00	2.88
Bran	10.27	6.68	2.33	19.50	52.50	8.72
Bran	9.65	6.25	2.38	28.58	43.78	9.36
Polish	8.83	18.06	18.48	35.02	11.07	8.44
Polish	9.00	18.37	16.50	42.61	6.38	7.14
Decorticated millet *	9.77	13.06	2.84	72.99	0.46	0.88
Decorticated millet *	9.16	11.40	2.81	75.14	0.23	1.26

* Extreme sizes.

A so-called " broom corn millet " (*Panicum miliaceum*), analyzed by Woll,[1] contained: water 11.30, protein 9.44, fat 3.81, nitrogen-free extract 61.14, fiber 10.76, and ash 3.55 per cent. The composition corresponds with that of true millet, but the name " broom corn millet " is misleading.

Under the name of " proso " 38 analyses appear in Chamberlain's bulletin.[2] The range and average composition follow:

Composition of Proso (Chamberlain)

	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	8.15	10.00	2.88	65.69	4.58	2.78
Max.	10.93	17.94	3.78	75.22	10.89	5.65
Average	**8.93**	**12.77**	**3.27**	**71.23**	**8.95**	**3.78**

Dunbar and Binnewies,[3] of the South Dakota State College, found in unbolted proso meal and proso flour (bolted), respectively: water 12.80 and 10.09, protein 15.86 and 14.90, fat 5.07 and 3.32, nitrogen-free extract 57.16 and 69.44, starch 59.65 and 69.15, fiber 6.25 and 0.80, and ash 2.86 and 1.45 per cent.

The average of 4 analyses of millet compiled by Lindsey[4] shows:

[1] Wisconsin Agr. Exp. Sta. Rep. 1899.
[2] U. S. Dept. Agr. 1909, Bul. **120.**
[3] J. Am. Chem. Soc. 1920, **42,** 658.
[4] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

water 12.0, protein 11.1, fat 3.7, nitrogen-free extract 62.9, fiber 7.7, and ash 2.6 per cent.

Proteins.—In samples analyzed by Bersch,[1] the protein nitrogen and amide nitrogen in millet and its products were respectively as follows: rough millet 1.83 and 0.02, bran 0.96 to 1.04 and 0.03 to 0.04, polish 2.71 to 2.79 and 0.09 to 0.23, and decorticated millet 1.76 to 1.94 and 0.01 to 0.33 per cent. The nuclein ranged from 0.70 in the polish to 0.40 in the decorticated millet.

Fat (Ether Extract).—The fat of the various products and by-products of millet examined by Bersch [1] showed the following figures for saponification number and iodine number, respectively: rough millet 216 and 60, bran 213 to 216 and 58 to 59, polish 210 to 212 and 58, and decorticated millet 213 to 214 and 56 to 61.

An extraction of ground hulled proso yielded in the hands of Dunbar and Binnewies [2] a mobile oil at first straw color, on standing light golden yellow. On standing out of contact with the air, crystals of an unknown substance, "prosol," which melted at 279° C., appeared. The substance contained 80.8 per cent of carbon and 10.1 per cent of hydrogen. It was believed to be a ketone alcohol in several respects allied to the phytosterols, in others, markedly different, and was assigned the tentative molecular formula $C_{24}H_{36}O_2$.

The fat itself had the following constants: specific gravity at 22.5° 0.9228, refractive index 1.4745, saponification number 181.5, iodine number (Hübl) 92.3, acetyl number 39.2, and Reichert-Meissl number 2.5. The free fatty acids reached 11.9 per cent, calculated as oleic acid, the unsaponifiable matter 2.52 per cent. Determination of the volatile acids yielded 0.36 per cent, calculated as formic, and of insoluble fatty acids 89.8 per cent. The combined mass of saturated and unsaturated insoluble acids had a saponification number of 195.9, an iodine number of 96.6, and a mean molecular weight of 286. Of the insoluble acids 14.7 per cent were saturated and 85.3 per cent unsaturated. Constants for these were, respectively: iodine number 24.4 and 123.8, neutralization number 187.3 and 314.0.

They conclude that the saturated acids consist of a large amount of palmitic and smaller amounts of carnaubic and daturic acids, whereas the unsaturated acids consist of oleic, linolic, and isolinolic acids.

Carbohydrates.—Bersch [3] reports the following results on starch and other nitrogen-free constituents (sugar, etc.), respectively: rough millet 62.56 and 0.31, bran 19.03 to 27.83 and 0.47 to 0.75, polish 34.12 to 41.59

[1] Loc. cit.
[2] Loc. cit.
[3] Loc. cit.

and 0.90 to 1.02, and decorticated millet 72.56 to 74.40 and 0.37 to 0.74 per cent.

Pillitz[1] found in the hulled grain: sugar 0.45 and dextrin 1.12 per cent.

Mineral Constituents.—The composition of the ash of millet, given by Haskins [2] in terms of parts per thousand of the grain, as recalculated in percentages of the ash follows:

K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	Cl	Undetermined *
%	%	%	%	%	%	%	%
11·2	1·4	0·7	9·5	22·0	0·3	0·3	54·6

* Mostly silica.

König [3] reports similar figures, including silica 56.02 per cent.

Minor Mineral Constituents. *Manganese.*—7.7 mg. per kilo, air-dry basis (Quartaroli).[4]

Copper.—5 mg. per kilo, air dry basis (Quartaroli).[4]

Zinc.—17 mg. per kilo, air dry basis (Bertrand and Benzon).[5]

JAPANESE BARNYARD MILLET

Panicum frumentaceum Roxbg. = *Echinochloa frumentacea* Link.

This species has a more compact inflorescence than common barnyard grass but is so closely allied as hardly to warrant separation into distinct species. It yields grain used as human food in the Orient and is grown to some extent in the United States as a fodder plant.

MACROSCOPIC STRUCTURE.—The six floral envelopes correspond to those of common millet. The three-nerved obtuse clasping *lower empty glume* is one-third the length of the five-nerved *upper empty glume* and the seven-nerved *flowering glume* of the abortive flower, all three being chaffy, brown or purple, and hairy on the nerves. A short point crowns the *glume* of the abortive flower. The *palet* of the abortive flower is thin and without nerves. Both the glume and the palet of the fruit are hard, smooth, and lustrous with faint longitudinal striations. The color varies, being commonly gray or brown-gray.

[1] Z. anal. Chem. 1872, **11**, 62.

[2] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[3] Chem. mensch. Nahr.-Genussm. Berlin, 1920, **2**, p. 873.

[4] Ann. chim. appl. 1928, **18**, 47.

[5] Bul. soc. hyg. aliment. 1928, **16**, 457.

MICROSCOPIC STRUCTURE. Thin Glumes.—Both the empty glume and the glume of the abortive flower have the same general structure. The *outer epiderm* consists of longitudinally elongated, wavy-walled cells alternating with short stiff hairs or their scars, each often with an adjacent crescent cell forming a twin. On the ribs and at the margins the *hairs* are longer, reaching 1 mm. Although thick-walled, the hair is so broad at the base as to make the lumen broader than the walls.

The **Thin Palet** of the abortive flower is more delicate in structure with short *hairs* on the margins.

Thick Glume and Palet.—These, closely enveloping the kernel, are like the corresponding parts of common millet in structure, being free from the elevations at the ends of the cells forming the characteristic wrinkles of German millet and the foxtails.

Pericarp.—The structure is practically like that of common and German millets and the foxtails. The strongly sinuous walls of the *epicarp* often form interlocking rounded dove-tails. On successive treatment with sodium hydroxide, acetic acid, and chlorzinc iodine, the layers are differentiated by the faint coloration from the spermoderm.

Spermoderm.—Structureless, but the cuticle stains golden yellow when treated as above.

Perisperm.—Not evident in specimens examined.

Endosperm.—*Aleurone cells* up to 60 μ in surface view and *starch cells* with rounded polygonal grains up to 18 μ are indistinguishable from those of common millet.

Chief Structural Characters.—Grain chaffy; outer envelopes thin, brown or purple, hairy on nerves; glume and palet, enveloping grain, hard, smooth, lustrous, with faint longitudinal striations.

Hairs of outer chaff long and short, stiff. Epicarp with sinuous often interlocking walls. Cross cells, tube cells, spermoderm, and starch grains as in green foxtail and German and common millets. Aleurone cells as in common millet.

BARNYARD GRASS

Panicum crus-galli L. = *Echinochloa crus-galli* Beauv.

Ger. Hühnerhirse.

This weed is so like the foregoing as hardly to warrant a specific name. It is common in cultivated soils of Europe and America, particularly, as the name indicates, where the ground is rich. In the variety *hispida* the hairs are strongly developed, and the point of the glume of the

abortive flower is extended into a long awn. The *flowering glume* and *palet* of the fruit vary from light yellow to nearly black in color.

PEARL MILLET

Pennisetum americanum Schum. = *P. typhoideum* Rich. = *Penicillaria spicata* Willd.

Fr. Millet chandelle. Sp. Panizo negro. Ger. Negerhirse.

Whether or not pearl millet originated in Africa, it has been extensively grown there since colonial days, and the genus to which it belongs is represented by several other species. It has been grown in India and other Asiatic countries since before the advent of Europeans and in tropical America since the early Spanish colonization.

As a human food it is of no little importance in Africa, being known as duchn, dohan, and by other names. In subtropical Europe and America it is grown as fodder.

MACROSCOPIC STRUCTURE.—The inflorescence is in dense spikes up to 2.5 cm. in diameter and up to over 30 cm. long. Each hairy *pedicel*, 1 mm. long, bears two spikelets, 5 mm. long, with an involucre of numerous upwardly barbed bristles equaling them in length. Each *spikelet* has two flowers, but only the terminal one is fertile. The spikelets resemble those of the foxtails and German millet in that bristles are present, but differ in that none of the chaff elements are transversely wrinkled. Hairs occur at the edges of the flowering glumes and on the wings of the palet.

There are two *empty glumes* of thin texture, one about one-quarter and the other nearly half the length of the spikelet. The five-nerved *flowering glume* and the two-nerved, two-winged *palet* of both fertile and sterile flowers are about the length of the spikelet, those of the sterile flower being of thinner texture. The exposed surface of the flowering glume of the fertile flower is lustrous.

At maturity, the *fruit*, showing from between its enclosing chaff, is easily removed by threshing, although grain enveloped by chaff and with bristles and pedicel attached occurred in the samples examined. The fruit varies up to 5 mm. long; it is largest at the apex, tapering to the narrow base, varying from oval to tear-drop shape. The top portion is pearl gray, shading to brown at the bottom. The brown color is well marked over the embryo, which is over half the length of the fruit, on the side facing the flowering glume. A dark spot occurs on the side opposite the embryo near the base.

MICROSCOPIC STRUCTURE.—Mitlacher's description [1] agrees in most details with the following, based on our own observations.

Pedicel.—The numerous *hairs* are often over 1 mm. long with lumen broader than the wall.

Bristles.—These vary from broad (150 μ) to slender. The broad forms bear, in addition to *short hairs*, *long hairs* like those on the pedicel; the slender forms are merely barbed with short thorn-like hairs forming a saw edge.

Empty Glumes.—In both, the elongated cells of the *outer epiderm* have thin, finely wavy walls. Short thorn-like *hairs* occur on the edges.

Flowering Glumes.—In the thicker parts four layers may be present: (1) *outer epiderm* with wavy-walled long cells, twin cells, and on the edges short thorn-like and long (700 μ or over) hairs, (2) *hypoderm* of thin-walled fibers, (3) *parenchyma* (only in parts), and (4) straight-walled *inner epiderm*. Mitlacher notes the occurrence of a raised rosette of cells about the base of some of the *hairs*.

On the flowering glume of the fertile flower the walls of the *outer epiderm* are more strongly thickened than on the flowering glume of the sterile flower.

Palets.—Both palets are practically the same in structure as the corresponding flowering glumes except on the wings where the cells of the *outer epiderm* have thinner walls, numerous *hairs* are present, and the underlying tissues are less strongly developed or absent.

Pericarp.—Four layers are present: (1) *epicarp* made up of longitudinally elongated cells with unusually thick, porous, sinuous walls, (2) *hypoderm* similar to the epicarp, one or two cells thick, (3) *spongy parenchyma* of branching, mostly transversely elongated *cross cells* as in maize, and (4) *tube cells*.

When fully developed, the walls of the *epicarp*, as seen in surface preparations, being strongly thickened and in addition sinuous and porous, show curious distorted beads not unlike those of the thick chaff of oats. Mitlacher evidently examined only underdeveloped specimens, as he found only thin wavy-walled cells with thickenings on the outer bends of the waves.

Spermoderm and **Perisperm,** if present, are inconspicuous and local.

Endosperm.—Körnicke and Werner [2] and Beneke [3] state that the *aleurone cells* may have blue contents. The color, however, is faint or lacking. More conspicuous is the frequent knobby thickening of the walls such as in the endosperm of coffee. Similar knobby thickenings

[1] Z. allg. esterr. Apoth.-Ver. 1901, 813, 831, 856, 875, 899, 928.
[2] Handbuch des Getreidebaues. Berlin, 1885.
[3] Landw. Vers.-Sta. 1889, **36**, 337.

occur in the aleurone cells of wheat (which see) about the end of the groove as seen in cross section but are not noticeable in surface view.

The *starch cells* contain grains practically the same as in foxtails and common and German millets. Polygonal and rounded forms, both with distinct hilum, are present, the maximum not exceeding 20 μ.

Embryo.—Not remarkable.

CHIEF STRUCTURAL CHARACTERS.—Kernel ovate or tear-drop shaped, pearl gray above, brown below, sometimes with chaff, numerous bristles, and pedicels attached. Chaff smooth, excepting hairs.

Chaff with elongated, wavy-walled cells and short twin cells. Hairs present on pedicel, bristles, edges of flowering glume, and wings of palet. Epicarp cells with much-thickened, porous, sinuous walls; cross cells forming spongy parenchyma. Aleurone cells often with knobby-thickened walls and faint blue contents. Starch grains of millet type (see Green Foxtail).

CHEMICAL COMPOSITION.—As analyzed by Church [1] and Balland,[2] the seed contains as follows:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Church	11.3	10.4	3.3	71.5	1.5	2.00
Balland:						
Min.	11.00	8.78	2.35	66.07	1.35	0.80
Max.	14.00	16.10	6.25	71.17	3.85	2.10

RICE

Oryza sativa L.

Fr. Riz. Sp. Arroz. It. Riso. Ger. Reis.

Rice is distinctly an Asiatic cereal both as to its origin and chief cultivation in modern times. As a wild plant it appears to have been distributed over a wide region, including China and India. It was cultivated in China and Japan at least 3000 B.C. and somewhat later in India. From India it traveled westward, reaching Syria and Egypt not long before the Christian era (De Candolle).

According to Stubbs, Dodson, and Browne,[3] its introduction into the

[1] Watt's Dict. Econ. Prod. India, Calcutta, 1889, **6**, Part 1, 30.

[2] Compt. rend. 1902, **135**, 1079.

[3] Louisiana Agr. Exp. Sta. 1904, Ser. 2, Bul. **77**.

United States dates from 1698, when seed was brought to the Carolinas. Soon after the end of the Civil War in 1865 its cultivation was undertaken in Louisiana, where it is now a crop of great importance.

Other types of rice are red rice (*O. rufipogon*), dry or mountain rice (*O. mutica*), early rice (*O. præcox*), and glutinous or clammy rice (*O. glutinosa*), which, although assigned specific names, are doubtless mere varieties. None of these is of great importance.

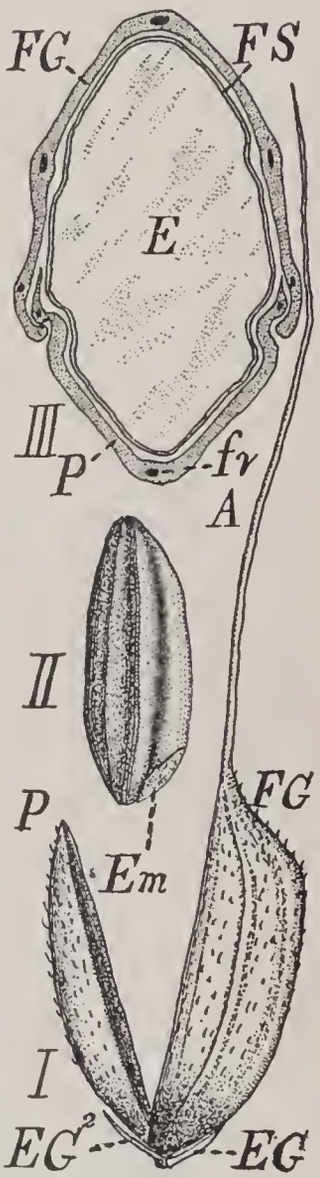


FIG. 66.—Rice. I envelopes (chaff). ×3. II kernel. ×3. III whole in cross section. ×12. *EG*, *EG*² empty glumes; *FG* flowering glume; *P* palet; *A* awn; *FS* bran coats; *E* endosperm; *Em* embryo; *fv* bundle. (A. L.W.)

MACROSCOPIC STRUCTURE (Fig. 66).—The spikelets are one-flowered with two minute *empty glumes* (*EG*) and (*EG*²), a *flowering glume* (*FG*) awnless or awned (*A*) at the very apex, and a somewhat smaller *palet* (*P*). The flowering glume has the usual five nerves and the palet three nerves, two of which are in the keels. Viewed with a lens, both the floral envelopes show a kind of cross hatching on the outer surface with longitudinal markings and finer cross markings. Because of these and the high silica content, the chaff is harsh and indigestible, unsuited even for animal food. A cross section (III) under a lens shows the curious manner in which the edges of the flowering glume fit into the longitudinal groove of the palet in front of the keels, also the narrow wings of the palet hugging close to the kernel.

Separated from the chaff or hulls, the *kernel* (caryopsis) (II) is characterized by several shallow longitudinal grooves which are formed by close contact with the ridges on the inner surface of the flowering glume and palet. The *embryo* is situated at the bottom on the side facing the flowering glume as in other cereals but is relatively small.

MICROSCOPIC STRUCTURE.—Sections of the chaff are cut with difficulty owing to their siliceous nature. For surface preparations boiling with 1 per cent sodium hydroxide is useful. The caryopsis separated from the whole grain or brown rice must be used for study of the bran coats, as ordinary white rice lacks the outer coats.

Flowering Glume.—This is essentially the same in structure as the palet.

Palet (Fig. 67, *P*; Fig. 68).—Four layers are present: *outer epiderm* (*ep*[1]) with longitudinal rows of nearly square cells with deeply sinuous,

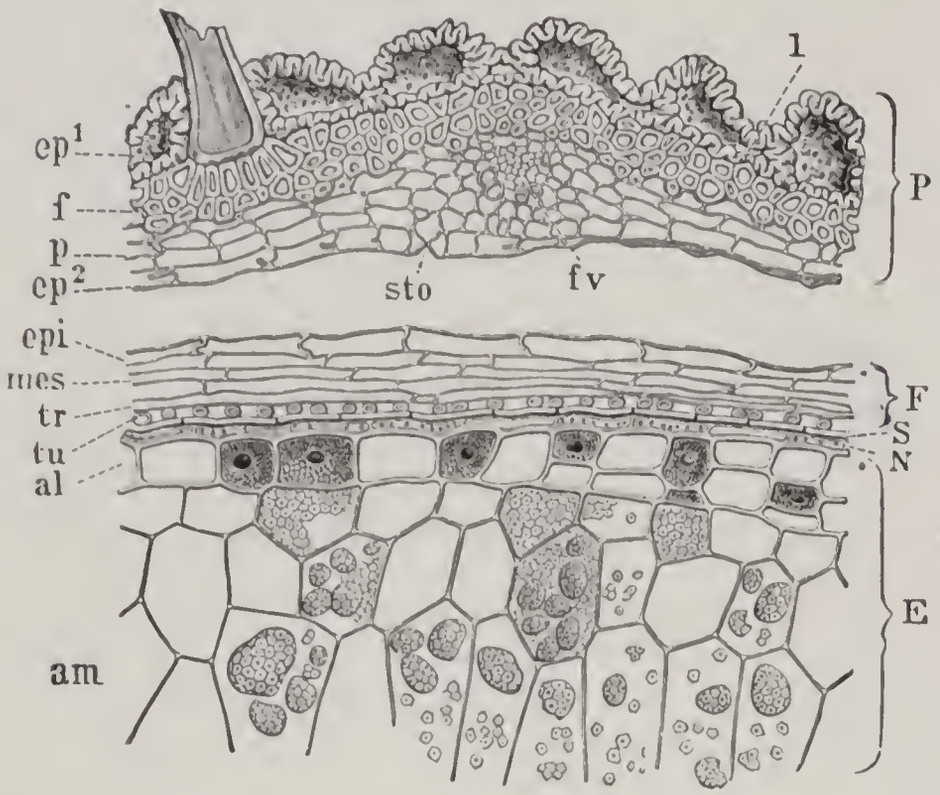


FIG. 67.—Rice. Palet and grain in cross section. *P* palet: *ep*[1] outer epiderm with hair, *f* hypoderm fibers, *p* spongy parenchyma with *fv* bundle, *ep*[2] inner epiderm with *sto* stoma. *F* pericarp: *epi* epicarp, *mes* mesocarp, *tr* cross cells, *tu* tube cells. *S* spermoderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *am* starch cells. ×160. (A.L.W.)

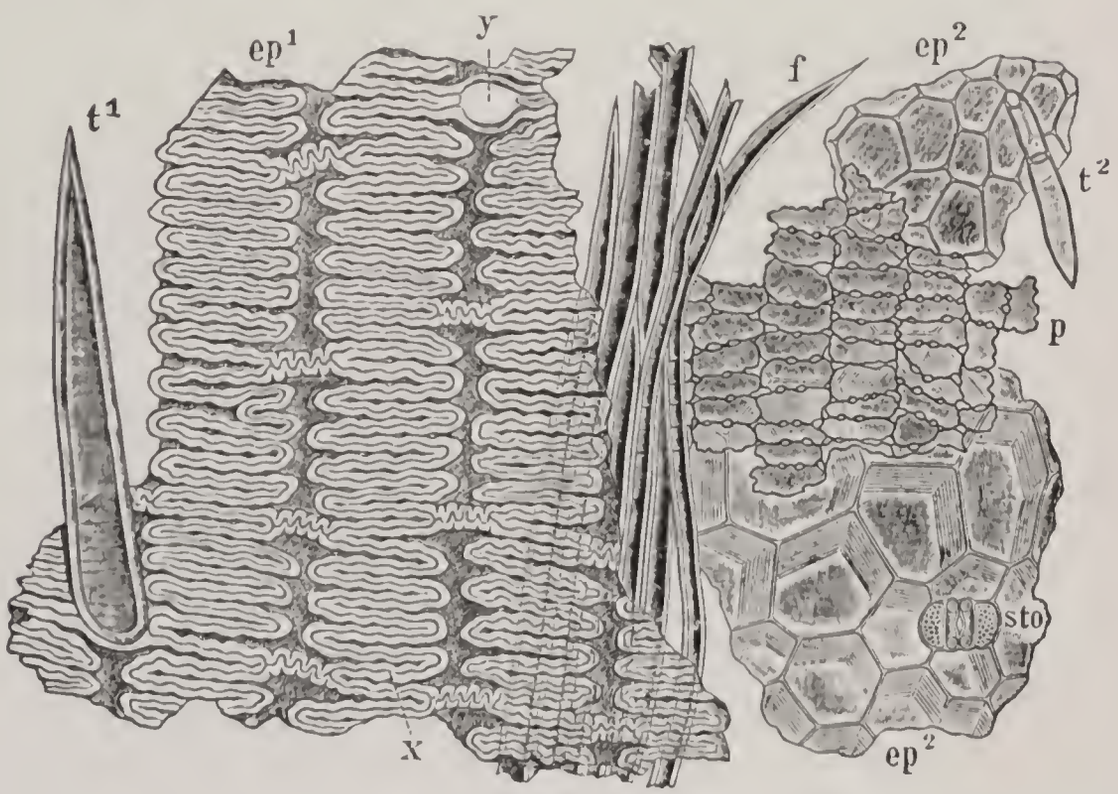


FIG. 68.—Rice. Palet in surface view. *ep*[1] outer epiderm with *x* sinuous cells, *t*[1] hair, and *y* hair scar; *f* hypoderm fibers; *p* spongy parenchyma; *ep*[2] inner epiderm with *sto* stoma and *t*[2] hair. ×160. (A.L.W.)

thick walls, interspersed with stiff straight *hairs* (t^1), (2) *sclerenchyma fibers* (*f*) often with numerous outgrowths on the side fitting into corresponding depressions of adjoining fibers or cells, (3) *spongy parenchyma* (*p*) with rather small quadrilateral cells, and (4) *inner epiderm* (ep^2) of polygonal cells elongated over the bundle but elsewhere isodiametric, interspersed with thin-walled unicellular or jointed *hairs* and broad stomata.

No other cereal has cells resembling those of the *outer epiderm.* As seen in surface view, the cells are not only end to end but side by side in rows. The walls are so deeply sinuous as to be really folded. In addition, each turn has sinuosities of its own although not deep. As is evident from cross sections, grooves follow along the longitudinal walls forming the striations noted with the lens. Cross furrows pass midway between the transverse rows of end walls.

The *hairs* of the outer epiderm are loosely attached and often missing, leaving conspicuous scars.

The *fibers* and *spongy parenchyma* are not unlike these layers in barley. Characteristic is the *inner epiderm* with isodiametric polygonal cells (except over the bundle) and the broad stomata. As in other cereals, the radial walls tend to fall over, bringing outer and inner walls together and forming two cell networks (Fig. 68, ep^2).

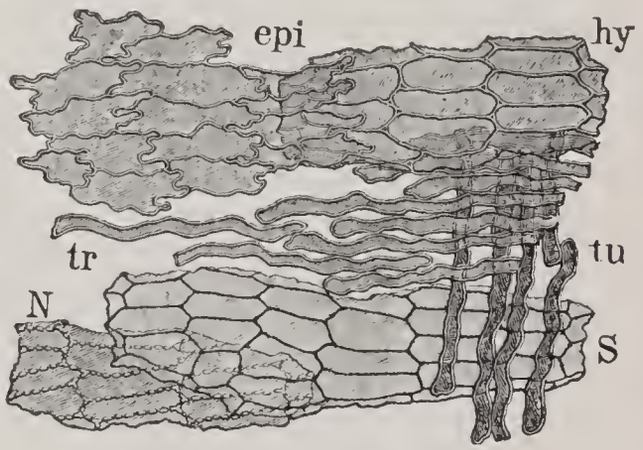


Fig. 69.—Rice. Bran elements in surface view. *epi* epicarp; *hy* hypoderm; *tr* cross cells; *tu* tube cells; *S* spermoderm; *N* perisperm. ×160. (A.L.W.)

Pericarp (Fig. 67, *F*; Fig. 69).—The structure of the pericarp, spermoderm, and perisperm is remarkable because five of the six layers are transversely elongated, whereas in the other common cereals this is true usually of only one layer and at the most of two layers.

The layers of the pericarp are (1) *epicarp* (*epi*), consisting of transversely elongated cells with deeply wavy end walls, (2) *hypoderm* or mesocarp (*mes, hy*), also of transversely elongated cells but with straight walls, (3) *cross cells* (*tr*) of transversely elongated vermiform cells, except for their transverse arrangement quite like the cells of the next layer, and (4) typical *tube cells* (*tu*).

Of these layers, the *epicarp* (*epi*) with the deeply sinuous end walls and arrangement of cells side by side in rows is highly characteristic in surface view. It is clearly seen by treating water mounts of scrapings with sodium hydroxide. Excepting wild rice and manna grass no other common cereal has transversely elongated epicarp cells.

The *cross cells* are much like those of maize, sorghum, and millet and somewhat like parts of the hypoderm of oats, but very different from the cross cells of wheat, rye, and barley.

Spermoderm (Figs. 67 and 69, *S*).—By cautious treatment of sections with sodium hydroxide on a slide, removal of the liquid with a bit of filter paper, and washing with water and finally with acetic acid in the same manner, the spermoderm and perisperm are both made evident. Subsequent treatment with chlorzinc iodine brings out the cuticle of the spermoderm as a yellow line and the perisperm as a blue line. Treatment of whole kernels removed from the chaff with the sodium hydroxide and then with acid, scraping, and mounting in the chlorzinc iodine brings out the same tissues in surface view. As in the outer layer of the spermoderm of wheat, the walls are delicate and the cells are side by side in rows but the elongation is transverse.

Perisperm (Figs. 67 and 69, *N*).—The treatment described in the foregoing section brings out the perisperm as well as the spermoderm. In surface view, the cells, recognized by their blue color, are transversely elongated and side by side in rows, as is true of the spermoderm, but are characterized by their beaded walls.

Attention was first called to the structure of both the spermoderm and perisperm by Winton [1] in 1905.

Endosperm (Fig. 67, *E*).—The *aleurone cells* (*al*) form a layer one cell deep over most of the kernel, but in parts they are two or three cells deep. In surface view they are about the same size as the aleurone cells of oats but have thinner walls.

Starch Cells (*am*).—The *starch grains* are not distinguishable from those of oats either in size (up to 10 μ) or their occurrence in aggregates of few or many grains. The absence of spindle-shaped individuals has been advanced as a valid distinction, but this is far from satisfactory.

Chief Structural Characters.—Kernel longitudinally striate, enveloped by harsh siliceous flowering glume and palet.

Outer epiderm of envelopes of isodiametric cells with thick, deeply folded walls. Epicarp, hypoderm, spermoderm, and perisperm of transversely elongated cells side by side in rows. End walls of epicarp cells deeply sinuous. Cross cells and tube cells worm-like. Starch grains small (10 μ), polygonal, in small and large aggregates as in oats.

MICROSCOPY OF RICE PRODUCTS.—Rough rice as obtained by threshing, not being suited for food, must be put through a process whereby the harsh siliceous hulls are removed, whatever treatment may follow.

[1] Moeller: Mikroskopie der Nahrungs- u. Genussmittel. Berlin, 2 Aufl. 1905, p. 214. Winton: Microscopy of Vegetable Foods. New York, 1st Ed. 1906, p. 108.

Hulled Rice.—Removal of the hulls is accomplished by means of stones. The product thus obtained was formerly regarded as unfinished and was quite unknown to the public but now is sold under the name of *brown rice* and recommended because of its high antiscorbutic qualities as an infant food. It consists merely of the whole grain exclusive of the worthless hulls.

Polished Rice.—The hulled rice, if not marketed in that form, is next decorticated to remove the skin or bran, consisting of the pericarp and layers within up to the starchy endosperm, also the embryo. Decortication formerly was carried out by pounding in large wooden mortars with wooden pestles, but this primitive method is now superseded by passing through modern machinery. The by-product of the operation is *rice bran.*

The process of polishing which follows rubs off irregularities of the surface and leaves the kernel in its finished form, the *rice* of commerce, *rice polish* being the by-product.

Disregarding the senseless if not unwholesome process of coating with glucose and talc often practiced, ordinary culinary rice consists almost entirely of the starchy endosperm with only part of the aleurone layer and traces of the bran tissues and germ.

Broken Rice, separated from the more attractive whole kernels, is placed on the market as such or utilized in the manufacture of mill products.

Puffed Rice is the polished rice puffed by the same process as is used in making puffed wheat (which see).

Rice Flour and *Grits* are analogous to the flour and grits of wheat and maize and are of a somewhat variable character according to the process of milling.

Rice flour is a common constituent of griddle-cake mixtures; the grits are utilized in brewing.

Rice Starch.—See Commercial Starches.

Rice Offals.—*Rice Hulls* serve for packing and various technical purposes. Their presence in rice feeds in considerable amount constitutes an adulteration.

Rice Bran and *Rice Polish,* sold under various names, are valuable cattle foods, the former containing more of the outer bran tissues, the latter more of the starchy endosperm.

CHEMICAL COMPOSITION.—The range in composition of rice from different countries exhibited at the World's Fair at Chicago in 1893, as reported by Wiley,[1] is as follows:

[1] U. S. Dept. Agr., Div. Chem. 1898, Bul. **13,** 1182.

Composition of Rice (Wiley)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Rough rice:	4						
Min.		9.0	8.2	1.4	65.0	9.4	3.3
Max.		11.5	8.4	2.0	65.7	11.5	4.7
Unpolished rice:	6						
Min.		10.9	7.3	1.6	73.3	0.9	1.0
Max.		12.6	10.5	2.3	77.3	1.0	1.2
Polished rice:	14						
Min.		11.8	5.4	0.04	75.6	0.3	0.3
Max.		13.2	10.3	0.5	81.7	0.6	0.7

Asiatic Rice.—Hooper [1] reports analyses of Indian rice from different provinces, and Cushman and Fuller [2] of samples collected in the open market at Singapore and Shanghai at the instance of the Siamese government. Their results for fat, fiber, and ash in the table below indicate great differences in the degree of polishing.

Composition of Asiatic Rice

	Samples	Wt. 100 kernels	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		grams	%	%	%	%	%	%
Hooper:	159							
Min.			8.94	6.58	0.31	73.63	0.32	0.73
Max.			13.15	7.69	2.83	82.05	1.00	1.56
Cushman and Fuller:	27							
Min.		0.892	9.19	7.38	0.10	78.67	0.16	0.40
Max.		1.725	11.54	8.94	0.94	80.87	0.83	1.23

Typical Ceylon rice and its products, prepared by hand labor, have been analyzed by Joachim and Kandiah [3] with the following average results:

[1] Agr. Ledger, 1908–9, **5**, 1.
[2] Eighth Int. Cong. Appl. Chem. 1912, **18**, 73.
[3] Trop. Agr. (Ceylon) 1928, **70**, 195.

Composition of Ceylon Rice and Products (Joachim and Kandiah)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	P_2O_5	CaO
	%	%	%	%	%	%	%	%
Paddies	12.01	6.69	1.91	63.84	10.40	5.26	0.54	0.078
Hand-husked rice	11.64	9.10	2.42	74.79	0.65	1.41	0.71	0.064
Polished rice	12.21	7.64	1.00	77.90	0.33	1.00	0.43	0.043
Bran	12.51	13.17	10.12	38.72	14.05	11.44	2.93	0.280
Husks	11.35	3.90	1.26	25.83	40.22	17.43	0.50	0.270

American Rice and By-Products.—Rough rice and the products of the rice industry have been studied by Ross [1] and by Browne and Chiquelin,[2] as shown below and on the following page:

Composition of Rice and Products (Ross)

	Water	Protein	Pure protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Rough rice	10.95	7.44	7.09	2.58	64.30	9.28	5.45
Rice from stones	12.12	8.09	8.09	2.10	72.11	3.03	2.55
Pounded rice	12.42	8.14	7.96	2.50	72.01	2.55	2.38
Rice from cooling floor	12.75	7.74	7.44	1.05	76.92	0.72	0.82
Clean rice	12.85	7.52	7.17	0.38	78.05	0.47	0.73
Bran	10.67	11.29	10.67	9.97	46.02	10.95	11.00
Polish	10.63	10.94	10.85	7.02	63.34	2.62	5.45
Hulls	8.27	2.89	2.89	0.85	34.99	38.15	13.85
Straw	8.97	4.72	4.72	1.87	32.21	32.25	19.97

The milling of rice and its mechanical and chemical effect upon the grain [3] are the subjects of an extensive study carried out on a commercial scale by Wise and Broomell. The rice was of two types: Honduras and Japan; four series of samples were analyzed in the former and three in the latter case, representing the products as they came from each machine in the mill.

In the table given on the following page, only such products as

[1] Louisiana Agr. Exp. Sta. 1889, Bul. **24.**

[2] Ibid. 1904, Ser. 2, Bul. **77.**

[3] U. S. Dept. Agr. 1916, Bul. **330.**

Composition of Rice and Products (Browne and Chiquelin)

	Water	Protein	Fat	N-f. ext.	Starch	Pento-sans	Fiber	Ash
	%	%	%	%	%	%	%	%
Rough rice	.....	9.88	.....	.....	69.67	2.14		
Polished rice	.....	6.56	.....	.....	77.55			
Bran (no hulls or grit)	8.57	13.41	14.30	46.48	18.80	.....	9.51	8.73
Bran (16 per cent hulls, 28 per cent grit)	9.84	9.88	9.91	44.26	25.42	8.95	14.76	11.55
Polish (22 per cent grits)	11.83	11.06	5.92	63.97	54.82	3.46	3.76	3.46
Polish *	10.79	8.53	6.95	69.14	.....	.....	1.80	2.95
Hulls	8.97	3.50	0.49	27.86	.....	17.24	41.89	18.29
Straw	10.84	3.31	0.59	38.31	.....	15.84	32.91	14.04

* Hulls and grit not determined.

Average Composition of Rice and Products (Wise and Broomell)

	Samples	Water	Protein	Fat	Pento-sans	Fiber	Ash
		%	%	%	%	%	%
Honduras type:							
Rough rice	4	11.27	7.48	1.58	5.90	8.67	5.40
Brown rice *	4	12.32	8.57	1.79	2.42	0.99	1.18
Fancy head	4	12.13	8.19	0.23	1.75	0.27	0.34
Second head	4	11.96	7.87	0.27	1.67	0.29	0.37
Screenings	4	12.75	7.69	0.34	1.80	0.28	0.47
Brewer's rice	4	12.26	7.81	0.33	1.81	0.37	0.62
Hulls	2	6.62	2.56	0.50	18.17	35.99	18.70
Bran	2	9.61	13.41	10.65	9.95	11.70	10.58
Polish	2	8.27	12.81	10.83	4.41	3.28	6.36
Japan type:							
Rough rice	3	11.05	6.50	1.74	5.48	7.93	5.14
Brown rice	3	12.38	7.24	1.52	2.28	0.85	1.13
Head	3	12.72	6.29	0.16	1.70	0.29	0.37
Screenings	3	12.85	6.54	0.23	1.72	0.31	0.45
Brewer's rice	3	12.53	6.62	0.24	1.64	0.31	0.41
Hulls	1	6.12	2.69	0.86	18.14	36.08	20.10
Bran	1	9.39	12.81	15.13	11.40	12.54	11.33
Polish	2	8.70	11.40	8.79	3.75	2.01	5.31

* From paddy machine.

enter commerce are included. Others not in the table are the rice from the hullers (a misnomer), from the pearling cone, from the brush, and from the trumbles—all representing stages in the removal of and separation from the bran, the hulls having been previously broken away by the hulling stone and removed by the fans. The paddy machine is used to separate the hulled from the unhulled grain. The rice that comes from the paddy machine is brown rice, now sold to some extent as a health food. Some of the samples of finished rice examined were coated with glucose and talc to improve their appearance, but the amount used (about 1 part of talc and 2 parts of glucose per thousand parts of rice) is not sufficient to alter appreciably the percentages of the constituents determined.

In the comprehensive investigation carried out by Fraps [1] in cooperation with Texas mills the usual proximate constituents, the sugars and pentosans, and the more important ash constituents were determined in the various finished products and by-products as well as in the rice after each stage in the process of hulling and polishing. The average yield of products and by-products per bag of rough rice (paddy), weighing about 162 lb. (73.5 kg.), for the three commonest types of rice grown in Texas follows.

	Hulls	Bran	Polish	Fancy rice	Second rice	Screenings rice	Brewers' rice	Loss and dirt
Japan.....	29	14	5	95	5	9	5	5
Honduras.....	34	15	5	60	19	18	7	5
Blue Rose.....	29	13	4	93	5	9	4	5

Brown rice is not included in the foregoing statement since at present it is placed on the market in relatively small amount.

In the following table is given a summary of analyses of the finished rice as well as of the offals used for cattle food.

Borasio [2] gives analyses of 14 samples of polished rice from various sources, of 8 samples of rough rice from Anatolia, and of 5 samples of gemma, consisting mostly of germ, which are summarized below.

Changes in Composition During Ripening.—Results by Tadokoro and Abe [3] are highly instructive. The ratio of pure protein to other

[1] Texas Agr. Exp. Sta. 1916, Bul. **191.**

[2] Giorn. risicolt. 1929, **19,** 131; 1930, **20,** 71, 88; Chem. Abs. **24,** 1677, 4557.

[3] J. Fac. Agr. Hokkaido Imp. Univ. 1930, **27,** 349.

Composition of Rice and Its By-products (Fraps)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Sand *
		%	%	%	%	%	%	%
Products								
Rough rice:	9							
Min.		9.64	7.23	1.39	60.95	6.99	4.30	4.24
Max.		13.59	8.95	2.07	66.41	10.10	6.42	4.24
Aver.		**11.68**	**8.09**	**1.80**	**64.52**	**8.89**	**5.02**	**4.24**
Brown rice:	16							
Min.		10.55	7.90	1.41	71.39	0.78	0.95	0.05
Max.		14.41	10.65	2.56	76.74	1.51	1.54	0.28
Aver.		**12.16**	**9.13**	**2.00**	**74.53**	**1.08**	**1.10**	**0.10**
Head (fancy) rice:	8							
Min.		11.94	6.60	0.25	75.11	0.35	0.30	0.06
Max.		13.84	10.04	0.98	79.85	0.48	0.94	0.13
Aver.		**12.57**	**9.01**	**0.50**	**77.02**	**0.40**	**0.50**	**0.09**
Second head rice:	9							
Min.		11.15	6.56	0.19	75.22	0.37	0.29	0.04
Max.		14.14	9.69	0.58	80.09	0.60	1.40	0.16
Aver.		**12.41**	**8.71**	**0.43**	**77.37**	**0.43**	**0.65**	**0.08**
Screenings rice:	8							
Min.		7.05	6.77	0.44	76.75	0.28	0.33	0.02
Max.		12.78	9.00	0.81	82.46	0.65	1.19	0.06
Aver.		**11.39**	**8.35**	**0.54**	**78.68**	**0.41**	**0.63**	**0.04**
Brewers' rice:	9							
Min.		6.85	7.59	0.31	74.84	0.42	0.38	0.10
Max.		14.05	9.85	2.08	81.61	0.73	1.11	0.18
Aver.		**11.78**	**8.88**	**0.95**	**77.14**	**0.56**	**0.69**	**0.13**
By-products								
Rough rice screenings:	7							
Min.		8.47	7.72	1.53	46.17	2.67	2.89	3.98
Max.		12.17	13.64	7.49	63.37	12.55	33.36	29.09
Aver.		**10.27**	**9.55**	**3.02**	**54.38**	**5.97**	**16.81**	**16.59**
Stone bran:	22							
Min.		6.79	7.46	4.28	29.63	14.09	9.74	6.63
Max.		11.64	11.78	11.55	47.97	25.94	20.99	17.97
Aver.		**9.69**	**9.77**	**7.66**	**36.73**	**20.92**	**15.23**	**12.06**
Huller bran:	23							
Min.		7.22	12.26	9.65	37.80	4.14	5.17	0.60
Max.		12.28	17.35	20.86	56.35	11.62	9.43	3.68
Aver.		**9.84**	**14.97**	**16.89**	**42.98**	**7.90**	**7.42**	**1.41**
Cone bran:	8							
Min.		8.54	12.50	11.78	38.35	2.50	5.39	0.39
Max.		11.50	16.52	20.32	55.94	8.79	8.61	1.77
Aver.		**9.77**	**15.39**	**15.97**	**46.13**	**5.66**	**7.08**	**0.88**
Rice hulls:	14							
Min.		6.11	1.78	0.54	24.56	31.43	14.83	13.69
Max.		10.95	5.00	1.98	36.83	46.37	22.00	20.84
Aver.		**8.49**	**3.56**	**0.93**	**29.38**	**39.05**	**18.59**	**17.52**
Rice polish:	10							
Min.		8.46	11.13	5.62	59.43	1.52	2.41	
Max.		10.76	14.45	12.95	67.28	2.79	5.57	
Aver.		**9 91**	**12.88**	**9.07**	**61.81**	**2.12**	**4.21**	

* Not determined in all samples.

Composition of Rice and Gemma (Borasio)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Sand
	%	%	%	%	%	%	%
Polished rice:							
Min.	10.80	6.00	0.24	76.19	0.35	0.40	
Max.	13.70	8.39	1.88	81.35	1.35	1.20	
Turkish rough rice:							
Min.	9.95	6.45	1.99	63.84	9.86	5.20	
Max.	10.50	7.90	2.35	65.93	10.12	5.80	
Gemma (germ):							
Min.	10.50	10.50	10.70	52.50	3.30	7.40	3.70
Max.	12.30	11.80	13.40	55.80	3.90	8.00	4.10

nitrogenous constituents showed a steady increase, but the total nitrogen remained nearly constant. The globulin and prolamine increased, the water-soluble protein decreased, and the glutelin fluctuated. These changes are the reverse of those that take place during germination. Of the products of hydrolysis of oryzenin, the amino compounds decreased, which, together with other changes, indicated that this protein reached its highest degree of condensation shortly before full ripeness, at which time also the maximum of glucose-forming carbohydrates was reached. The ash and phosphorus content of the starch gradually decreased while the saponification number of the fat increased.

Water.—M. Kondo and Okamura [1] after extensive comparative studies conclude that (1) the kernels of rough rice are as hygroscopic as those of hulled rice, notwithstanding the low hygroscopicity of the hulls, (2) rough rice dries more readily than hulled, (3) rough rice dries more uniformly than hulled, hence the kernel is not so brittle although less resistant to crushing, (4) when the kernels of rough rice contained 9.7 to 16.4 per cent of water, hulled rice under the same conditions contained 0.3 to 1.0 per cent more, the hulls from the latter, however, contained 1.4 to 2.9 per cent less than those from the rough rice.

The same investigators [2] showed that brown-colored rough rice (Tschamai) is produced if the blooming plants are set out during a rain, and that green kernels (Aomai) are due either to incomplete ripening or drying in the shade or under cloudy skies, further that transverse

[1] Ber. Ohara Inst. landw. Forsch. 1929, **4**, 127, 147, 163, 511.
[2] Ibid. 1929, **4**, 173; 1930, **4**, 413, 429.

cracks (Doware) of the hulled kernels are due to absorption of water after drying, hence it is important to store the rice in air-tight containers. They further show[1] that in order to preserve the germinating power hulled rice should be dried to 10 to 12 per cent of water and kept below 30° C. in air-tight containers.

Proteins. *Oryzenin.*—While searching for the cause of beri-beri, Rosenheim and Kajiura[2] undertook an investigation, only the preliminary announcement of which appears to have been published, although others have continued the work. They state that the bulk of the protein consists of oryzenin, which, being a glutelin, is insoluble in water, salt solution, and alcohol but dissolves in 0.2 per cent potassium hydroxide. Only traces of alcohol-soluble protein and small amounts of albumin and globulin are present.

By reducing the strength of the solvent solutions, Kondo and Hayashi[3] diminished the alteration of the proteins during the process of preparation. They also determined that the optimum for flocculation of the glutelin from the alkali solution is near the point of absolute neutrality.

Jones and Csonka[4] prepared the glutelin of polished rice by precipitation from the 0.2 per cent sodium hydroxide extract with ammonium sulphate added to 3 per cent saturation. Thus prepared it has an isoelectric point (*p*H) of 6.45. Csonka, Horn, and Jones[5] give −65.1° as the specific rotation at 20°.

Prolamines are present in small amount, if at all, in the inner endosperm. Suzuki, Yoshimura, and Fugi[6] found only 0.11 per cent of nitrogen soluble in 60 per cent alcohol, although in the bran they found 1.16 per cent.

Globulins.—Suzuki, Yoshimura, and Fugi[7] have reported in white rice and rice bran 0.17 and 1.37 per cent, respectively, of nitrogen soluble in 10 per cent salt solution.

Globulins coagulating at 74° and 90°, respectively, have been separated by Jones and Gersdorff[8] from the brine extract of polished rice.

By Sörensen's method, K. Kondo and Ito[9] isolated two globulins, one

[1] Ibid. p. 315.
[2] J. Physiol. 1908, **36**, LIV, LV.
[3] Mem. Col. Agr. Kyōtō Imp. Univ. 1926, p. 37.
[4] J. Biol. Chem. 1927, **74**, 427.
[5] Ibid. 1930, **89**, 267.
[6] J. Col. Agr. Imp. Univ. Tokyo 1909, **1**, 77.
[7] Loc. cit.
[8] J. Biol. Chem. 1927, **74**, 415.
[9] J. Chem. Soc. Japan 1930, **51**, 67.

amorphous, the other crystalline, the former being much higher in diamino nitrogen. particularly in the form of cystine, histidine, and arginine.

Ultimate Composition.—Analyses of the two globulins of Jones and Gersdorff, the glutelin (oryzenin) of Jones and Csonka, and the globulin and glutelin of Ito, Watanabe, and Kitahara[1] follow:

	Globulin (74°) (J. and G.)	Globulin (90°) (J. and G.)	Glutelin (J. and C.)	Globulin (I. et al.)	Glutelin (I. et al.)
	%	%	%	%	%
Carbon	52.83	49.15	52.58	50.8 –52.5	50.6 –53.3
Hydrogen	6.77	7.86	6.42	7.0 – 7.6	7.0 – 7.7
Nitrogen	16.31	17.94	17.57	16.5 –17.3	16.5 –17.3
Sulphur	0.98	1.45	1.65	0.44– 1.15	0.53– 0.64
Ash	0.29	1.64	0.38	....	0.31– 0.79
*p*H	.....	.....	.....	5.5 – 4.6	6.2 – 5.0

Amino Acids of Rice Proteins.—Suzuki, Yoshimura, and Fugi [2] in their studies of the solubility of the nitrogen of white rice and rice bran, found that 0.2 per cent sodium hydroxide dissolved 0.85 and 1.51 per cent, respectively. The glutelin obtained by Ritthausen's method, on hydrolysis, yielded: alanine 3.7, leucine 14.3, aspartic acid 0.4, glutamic acid 14.5, tyrosine 0.5, phenylalanine 2.0, proline 3.3, arginine 1.6, lysine 0.86, histidine 0.81, and ammonia 2.33 per cent. In rice bran the following results were obtained: leucine 8.6, glutamic acid 4.7, tyrosine 0.3, arginine 3.4, histidine 0.88, and ammonia 1.13 per cent. Several of these results are lower than found by later investigators.

Kajiura,[3] reporting further on the unfinished work of Rosenheim and Kajiura, states that the amino acids of oryzenin differ materially from those of wheat glutenin.

Osborne, Van Slyke, Leavenworth, and Vinograd [4] obtained from oryzenin relatively large amounts of basic amino acids as follows: cystine 1.26, arginine 9.15, lysine 4.26, and histidine 3.32 per cent.

Determination of some of the amino acids, made by Jones and coworkers [5] in the globulins and glutelin gave the following results:

[1] Gifu Imp. Col. Agr. (Japan) 1930, Bul. **13.**
[2] Loc. cit.
[3] Bio.-Chem. J. 1912, **6,** 71.
[4] J. Biol. Chem. 1915, **22,** 259.
[5] Loc. cit.

	Globulin coagulating at 74°	Globulin coagulating at 90°	Glutelin (oryzenin)
	%	%	%
Cystine	2.25	2.89	2.35
Tyrosine	5.60	7.53	.....
Tryptophane	2.69	2.32	.....
Arginine	7.85	15.18	11.13
Lysine	7.14	3.63	4.73
Histidine	2.42	3.01	2.39

The *Nitrogen Distribution* in percentages of the total nitrogen, as found by Osborne et al., corrected for solubility of the bases, follows:

	%
Humin N	1.59
Cystine N	0.88
Arginine N	17.69
Lysine N	4.90
Histidine N	5.39
Amino N of filtrate	52.13
Non-amino N of filtrate	5.28
Amide N	11.33
Total	99.19

Oryzanin, which must not be confused with oryzenin, is the crude material isolated from rice bran by Suzuki, Shimamura, and Odake[1] which contains a substance to which unpolished rice owes its antiscorbutic properties. The complex has an acid reaction, is soluble in water and dilute alcohol, and gives certain protein reactions. It is prepared by successive digestions of defatted rice bran with alcohol, precipitation after dealcoholizing and acidifying the extract with phosphotungstic acid, decomposition of the precipitate with barium hydroxide, removal of the barium from the solution, and evaporation. This extract, which contains also nicotinic acid, is further purified. Hydrolysis with acid yields choline, glucose, and two acids, $C_{10}H_8NO_4$ and $C_{18}H_{16}N_2O_9$. Although the pure substance was not isolated, the work is of great interest because it was along the same line as that carried out at about the same time by Funk, thus marking the beginning of the study of the vitamins.

Protein of Glutinous and Non-Glutinous Rice.—Analogous to other cereals, rice kernels differ in their relative amounts of horny and starchy

[1] Biochem. Z. 1912, **43**, 89.

endosperm. A comparison of results by Kinsuke Kondō [1] on the nitrogen of glutinous and non-glutinous Yettsu rice extracted by the usual solvents for the individual proteins, follows:

	Glutinous	Non-glutinous
	%	%
Nitrogen soluble in:		
Water	0.1156	0.0646
70 per cent alcohol	0.0442	0.0288
10 per cent salt solution	0.1292	0.0976
0.2 per cent sodium hydroxide solution	0.6596	0.3366
0.2 per cent sodium hydroxide solution (2nd extract)	0.1496	0.1445
	1.0982	0.6721
Total nitrogen	1.2240	1.0564

Ultimate analyses of the 0.2 per cent sodium hydroxide fractions of the glutinous and non-glutinous samples gave, respectively: carbon 57.09 and 50.82, hydrogen 9.96 and 8.68; nitrogen 16.97 and 17.75, sulphur 0.87 and 1.16, and oxygen 15.11 and 21.59 per cent.

The authors named also studied the refraction of the proteins of both kinds of rice and give a formula for its calculation, employing constants for both kinds of rice.

Extensive studies by Tadokoro, Nakamura, and Watanabe [2] led to the conclusion that oryzenin is present in glutinous rice in larger amount than in common rice. They further showed that the oryzenin prepared from glutinous varieties contains more COOH groups and fewer NH_2 groups than that from non-glutinous varieties. They also found that the oryzenin of glutinous rice contains more mono-amino nitrogen but less amide, arginine, lysine, and free amino nitrogen than that of non-glutinous rice. Both forms have the same content of tyrosine and tryptophane.

Nitrogen Distribution in Polished Rice.—Kurosawa [3] found the following distribution of nitrogen in polished rice: arginine nitrogen 10.89, histidine nitrogen 8.89, and cystine nitrogen 2.67, the results being in percentages of the total nitrogen. He further found cystine 0.87, tyrosine 3.51, and tryptophane 0.88 per cent, calculated to the dry rice.

[1] J. Chem. Soc. Japan 1921, **42**, 828.
[2] J. Col. Agr. Hokkaido Imp. Univ. 1925, **14**, 129.
[3] J. Tokyo Chem. Soc. 1919, **40**, 551

Free Amino Acids, Acid Amides, and Polypeptides.—In comparing the nitrogenous constituents of rice with those of other cereals, Jodidi [1] determined the protein and non-protein nitrogen and forms of non-protein nitrogen. Results are also given in the original publication on nitrogen of the phosphotungstic acid precipitate and of the humin precipitate that separated in the determination of acid amide nitrogen.

Distribution of Non-protein Nitrogen in Rice (Jodidi)
(Percentage in total nitrogen)

	Protein N	Non-protein N	Amino acid N	Acid amide N	Peptide N
	%	%	%	%	%
Wataribune	95.33	5.02	0.72*	0.14*	0.82*
Blue rose	95.92	4.00	1.38*	0.16*	1.64*
Honduras	97.12	4.02	0.98	0.24*	1.07*

* Hot water extraction.

Fat.—Rice oil is obtained from the bran and "polish" removed in the preparation of polished rice. The oil, as well as the offal from which it is obtained, rapidly increases in acidity unless specially treated. Browne [2] has shown that this deterioration is due to the action of an enzyme, *lipase*, on the fat. In some cases he noted that the rice oil contained nearly 90 per cent of free acid amounting to 8 to 12 per cent in the feeds.

By heating at 200° F., the enzyme is destroyed. Oil from a sample of fresh bran six hours after milling contained 12.5 per cent of free fatty acids. Oil from the same bran heated and unheated, after standing one month, contained, respectively, 24.0 and 62.2 per cent of free fatty acids. As further evidence Browne [3] added a cold water solution of rice bran to neutral castor oil. In one week the free fatty acids of the oil had reached 16 per cent.

Physical and Chemical Values.—In the following table are compiled the results obtained on rice oil by Browne,[4] Tsujimoto,[5] Garelli,[6]

[1] J. Agr. Res. 1927, **34**, 309.
[2] Loc. cit.
[3] J. Am. Chem. Soc. 1903, **25**, 948.
[4] Loc. cit.
[5] Chem. Rev. Fett-Harz-Ind. 1911, **18**, 111.
[6] Ann. chim. appl. 1917, **8**, 109.

Takahashi,[1] and Jamieson,[2] and in rice bran oil by De'Conno and Finelli:[3]

VALUES OF RICE OIL

	Sp. gr. 15.5° C.	Ref. index 20° C.	Melt. point	Saponification No.	Iodine No.	Reich.-Meissl No.	Hehner No.	Acid No.	Unsap. matter
			° C.						%
Rice oil:									
Browne	0.8907	.....	24	193.5	91.6	1.1	*	166.2	.....
Tsujimoto	0.9273	1.4742	.....	184.9	107.6	.....	†	34.7	4.8
Garelli:									
Extracted	.....	.....	25–26	186.0	99.7	.....	95.2	90.0	3.2
Expressed	0.918	.....	.....	179.4	.....	.....	94.3	13.8	0.7
Expressed	0.913	.....	.....	189.7	.....	.....	95.0	101.5	0.9
Takahashi:									
North Japan	0.9236	1.4704	.....	189.9	105.8	0.6	96.6	122.2	3.7
South Japan	0.9254	.....	.....	183.8	104.7	0.7	96.0	14.4	4.0
Korea	0.9276	1.4713	.....	183.5	108.6	1.2	92.1	11.9	4.2
Formosa	0.9208	.....	−5	192.2	103.1	1.7	94.1	81.3	3.9
Jamieson	.....	.....	.....	185.3	99.9	.....	.....	73.7	4.6
Rice bran oil:									
De'C. and F.	.....	.....	24–25	189.1	100.8	.....	.....	101.2	1.4

* Mean molecular weight of insoluble acids 289.3, melting point 36°.

† Mean molecular weight of insoluble acids 259.4, melting point 58.5°, saponification number 216.3.

From the foregoing figures it is evident that the oil obtained by Browne, aside from acidity, was somewhat different from that examined by the Japanese chemists, especially as regards melting point and iodine number. Garelli's and Jamieson's results are between the two extremes. The explanation doubtless lies in differences in the bran or polish extracted and perhaps to some extent in the kind of solvent.

Tsujimoto reported the following additional results on the total fatty acids: specific gravity at 100° C. 0.8528, melting point 30.5°, saponification number 182.73, and iodine number (Wijs) 109.47.

Fatty Acids of Rice Oil.—The calculations of Tsujimoto, Takahashi, and Jamieson, as given in the following table, show reasonable agreement except as regards the minor constituents. The figures represent percentages of the fatty acids in the total fatty acids, except in the case of Jamieson's analyses where they represent percentages of the glycerides of the fatty acids in the oil containing 4.6 per cent of unsaponifiable matter.

[1] J. Tokyo Chem. Soc. 1919, **40**, 191.
[2] J. Oil & Fat Ind. 1926, **3**, 256.
[3] Ann. chim. appl. 1930, **20**, 26.

FATTY ACIDS OF RICE OIL

	Lignoceric	Behenic	Arachidic	Stearic	Palmitic	Myristic	Oleic	Linolic
	%	%	%	%	%	%	%	%
Tsujimoto	.....	.....	.....	.....	20.0	.....	45.0	35.0 *
Takahashi:								
North Japan	.....	+	+	+	+	+	47.2	31.5
South Japan	.....	0.5	3.8	+	18.9	+	46.1	31.5
Korea	.....	0.6	3.5	+	18.8	+	42.6	34.8
Formosa	.....	0.6	4.3	+	20.0	+	45.0	30.0
Jamieson	0.4†	.....	0.5†	1.8†	12.3†	0.3†	41.0†	36.7†

* "Isolinolein."

† Calculated as glyceride.

The oil examined by Jamieson contained 14.7 per cent of saturated and 74.3 per cent of unsaturated acids and had an acid value of 73.7.

Weinhagen [1] states that *rice bran* contains 10.94 per cent of fat, 73 per cent of which is liquid and 27 per cent solid. The liquid portion consists of 91 per cent of fatty acids (59 per cent oleic and 31.8 per cent palmitic acid) and 5.3 per cent of phytosterol; the solid fat consists of 90.6 per cent of fatty acids (practically all palmitic acid) and 4.7 per cent of phytosterol. He appears to have overlooked linolin and the less abundant glycerides.

Hari [2] states that the fat of the *rice embryo* is essentially the same as that of the polish, consisting chiefly of the glycerides of oleic, linolic, and palmitic acids.

Phytosterol.—Tsujimoto [3] by recrystallizing several times obtained from the unsaponifiable matter crystals of "phytosterol" melting at 136 to 137° C.

Takahashi [4] found that only 30 per cent of the unsaponifiable matter is crystallizable.

Weinhagen [5] states that a saturated hydrocarbon, $C_{27}H_{18}$, may be separated from the phytosterol by fractional crystallization from alcohol.

Nabenhauer and Anderson [6] extracted from rice bran with ether about 10 per cent of oil consisting largely of fatty acids. The unsaponifiable matter amounting to about 5 per cent of the oil consisted chiefly of a viscous oil which on distillation yielded a yellowish to light brown oil, the

[1] Z. physiol. Chem. 1917, **100**, 159.

[2] Acta Scholæ Medicinalis 1925, **7**, 515.

[3] Loc. cit.

[4] Loc. cit.

[5] Loc. cit.

[6] J. Am. Chem. Soc. 1926, **48**, 2972.

higher fractions containing phytosterol. In the crystalline portion they found myricyl alcohol, dihydrositosterol, stigmasterol, and phytosterol which is not probably homogeneous sitosterol.

Carbohydrates. *Sugars.*—According to analyses by Fraps,[1] both reducing sugars and disaccharides occur in considerable amount in the bran and polish but in very small amount in the finished rice. Even the hulls contain more than the latter. Average results appear in the following table:

Sugars and Pentosans in Rice and By-products (Fraps)

	Reducing sugar	Disacchorose sugar	Pentosans
	%	%	%
Products:			
Brown rice	0.12	0.79	2.12
Fancy head rice	0.14	0.17	1.75
Second head rice	0.10	0.23	1.86
Screenings rice	0.05	0.30	1.75
Brewers' rice	0.17	0.24	1.71
By-products:			
Stone bran	0.78	1.15	13.87
Huller bran	1.20	4.51	7.76
Cone meal	1.55	2.15	5.81
Hulls	0.24	0.43	18.14
Polish	1.27	2.26	3.47

Starch.—Tanaka [2] has sought an explanation for the reddish coloration produced in the starch of glutinous rice by iodine solution. He found that this starch does not contain Nägeli's amylodextrin or erythrodextrin or special proteins to which some have attributed the phenomenon. It is his belief that the reaction is a characteristic of the starch itself, which is capable of dissolving only a minute amount of iodine, and that no common starch, colored blue with iodine, is present in glutinous rice. He further showed that the starch of glutinous rice is rapidly hydrolyzed by diastase to dextrin with the formation of less maltose than obtained from potato or common rice starch. This difference is explained by the presence of a greater amount of amylopectin or an analogous substance which produces a dextrin more slowly hydrolyzed by diastase than that of common starch.

[1] Loc. cit.

[2] J. Ind. Eng. Chem. 1912, **4**, 578.

Tanaka further states "that the starches of 'mochi-awa' (glutinous millet), 'mochi-kibi' (glutinous variety of *Panicum miliaceum* L.) 'morokoshi' (*Andropogon Sorghum* Brot. var. *vulgaris* Hack.), and 'nien kaoling' (glutinous variety of 'kaoling') are also colored red by iodine solution."

Pentosans.—The results by Browne and Chiquelin given in a foregoing table show that the pentosans occur in greater amount in the polish (3.46 per cent) and bran (8.95 per cent) than in the rough rice (2.14 per cent) and in still greater amounts in the straw (15.84 per cent) and hulls (17.24 per cent). Similar figures are given by Fraps [1] in the table above.

Methylpentosans, according to Katayama,[2] occur in all rices and rice starches up to nearly 1 per cent. Ordinary rice contains more than glutinous and unpolished more than polished rice.

Phosphorus-Organic Compounds.—Bernardini [3] gives the distribution of the phosphorus in rice embryo and the whole seed, respectively, as follows: as lecithin 0.04 and 0.003, as lecithide (combined lecithin?) 20.2 and 0.018, as phytin 5.14 and 0.436, as nuclein 0.76 and 0.502, and as inorganic salt 0.04 and trace; total 6.20 and 0.959 per cent.

Borasio,[4] in the product known as "Gemma," consisting mostly of germ, reports 2.40 per cent of phosphorus, of which 1.70 was from phytin and 0.003 from lecithin.

From polished rice Iwata [5] isolated a toxic substance, *lysolecithin*, ($C_{24}H_{50}NPO_7$) which melts in a sealed tube at 262 to 264° C. with decomposition and is levorotatory. On hydrolysis it yields palmitic and glycero-phosphoric acids and choline.

Phytin.—Suzuki, Yoshimura, and Takaishi [6] proved that rice bran contains 8 per cent of phytin and that a ferment in rice bran splits this up into inosite and phosphoric acid (see Wheat). Bernardini and also Borasio, as noted above, found that the greater part of the phosphorus exists as phytin.

Thompson [7] found that samples of unpolished rice, polished rice, and rice bran contained, respectively, 0.321, 0.14, and 2.291 per cent of phosphorus. By extraction with 0.02 per cent hydrochloric acid and precipitation with alcohol, rice bran was found to contain 8.22 per cent

[1] Loc. cit.
[2] J. Chem. Ind. Japan 1915, **18**, 1364.
[3] Atti accad. Lincei 1911, **21**, 283.
[4] Giorn. risicolt. 1929, **19**, 131.
[5] Proc. Imp. Acad. (Japan) 1930, **6**, 212.
[6] Bul. Col. Agr. Tokyo Imp. Univ. 1907, **7**, 503.
[7] J. Agr. Res. 1915, **3**, 425.

of phytin whereas polished rice yielded none. Preparations of barium phytate made from unpolished rice and rice bran contained less barium and phosphoric acid than Anderson found to correspond with tribarium-inosite hexaphosphoric acid. Inosite prepared from the barium phytate melted at 223° C. (uncorrected) and gave Scherer's reaction.

Rather [1] extracted 36 and 44 grams of crude inosite phosphoric acid from 1250 grams of rice bran and rice polish, respectively. From this he prepared the strychnine and silver salts. Analyses of these correspond with the formula for inosite pentaphosphoric acid. Determinations by Rather of the phosphorus existing in the form of inosite pentaphosphoric acid and of inorganic combination, expressed as percentage of the total acid soluble phosphorus, gave respectively as follows: rice bran 87 and 19 per cent; rice polish 93 and 10 per cent.

Enzymes. *Protease.*—Calculated as trypsin at the optimum temperature of 30 to 40° C., Giesen [2] found 0.70 per cent.

Catalase.—Sampietro[3] obtained results indicating that there is a relation between the germinative capacity and the catalase content. Borasio [4] was unable to find any such relation, although he states that other enzymes may influence germination.

Effects of Storage.—In experiments by Noguchi,[5] rice harvested and stored in August was kept in storage until March, then examined monthly until mid-winter. Amylase suddenly dropped in July, then remained about constant; lipase gradually decreased until August, when it decreased more rapidly; catalase gradually decreased throughout the experiment; oxidase showed little change; and peroxidase decreased abruptly in August, then remained constant until Spring.

Mineral Constituents.—The average results of analyses of hulled rice ash as given by Wolff and a single analysis of Japanese rice as obtained by Kellner and Nagaoko [6] agree quite closely, being as follows:

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
Wolff	21.73	5.50	3.29	11.20	1.23	53.68	0.62	2.74	0.10
K. and N.	22.47	4.55	2.93	12.30	1.63	48.31	0.23	6.53	0.91

[1] J. Am. Chem. Soc. 1918, **40,** 533.
[2] Inaug. Dis. Bern, 1909.
[3] Giorn. risicoltura 1923, **13,** 133.
[4] Ibid. 1924, **14,** 143.
[5] J. Sci. Agr. Soc. Japan 1923, **245,** 115.
[6] Col. Agr. Imp. Univ. Tokyo, 1893, Bul. **12.**

Fraps[1] determined the principal ash ingredients in rough rice, brown rice, the different grades of finished rice, and the by-products, as shown in the table below. The deficiency of all the valuable ash constituents in polished rice as compared with brown rice and the bran is striking.

Mineral Constituents of Rice and By-products (Fraps)

	K_2O	CaO	MgO	P_2O_5	Ash*
	%	%	%	%	%
Products:					
Rough rice	0.25	.....	.....	0.54	.....
Brown rice	0.25	0.09	0.14	0.63	0.16
Fancy head rice	0.07	0.04	0.06	0.23	0.09
Second head rice	0.09	0.05	0.08	0.27	0.08
Screenings rice	0.05	0.04	0.05	0.26	0.04
Brewers' rice	0.16	0.04	0.09	0.32	0.13
By-products:					
Hull ashes	0.58	0.57	0.12	0.57	96.97
Stone bran	0.61	0.16	0.52	1.39	.....
Huller bran	1.42	0.12	1.21	3.47	.....
Cone meal	1.58	0.09	1.21	3.19	.....
Hulls	0.24	0.11	0.09	.....	.....
Polish	0.66	0.09	0.62	1.73	.....

* Acid insoluble.

The ash of rice embryo, as analyzed by Bernardini,[2] contained in percentages of the embryo: potash 1.691, soda trace, lime 0.279, magnesia 1.389, ferric oxide 0.060, manganic oxide trace, and silica 0.250.

Silica in the ash of unshelled rice may reach 20 per cent or more.

Minor Mineral Constituents.—The peculiar conditions under which rice is grown, such as on submerged ground, may influence the kind and amount of minor constituents.

Iron.—In Sherman's compilation,[3] appear results of determinations of iron calculated as the metal in 3 samples: polished rice 6 (Sherman), rice from Japan 9 (Häusermann), and rice for feeding animals 19 mg. per kilo (Bunge). Polished rice 13, rice polish 171 mg. per kilo, dry basis (McHargue).[4]

Aluminum.—White rice 1.4 mg. per kilo, dry basis (Bertrand and Lévy).[5]

Manganese.—Polished rice 10, rice polish 112 mg. per kilo, dry basis (McHargue).[4]

[1] Loc. cit.

[2] Loc. cit.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185.**

[4] J. Am. Soc. Agron. 1925, **17,** 368.

[5] Compt. rend. 1931, **192,** 525.

Rice 7.8 and 8.3 mg. per kilo, air-dry basis (Quartaroli).[1] Rice, 5 varieties, 43 to 61 mg. per kilo, dry basis (Davidson).[2]

Copper.—Decorticated rice 6.4 mg. per kilo (Guerithault).[3] Polished rice trace, rice polish 8 mg. per kilo, dry basis (McHargue). Rice 1.32 and 1.66 mg. per kilo, air dry basis (Quartaroli).[1]

Zinc.—Polished rice 7.5, rice polish 76 mg. per kilo, dry basis (McHargue). Unshelled Japanese rice 14.7 mg. per kilo, air dry basis (Birckner).[4] Polished rice 2.9, rice bran 33.3 mg. per kilo, dry basis (Bertrand and Benzon).[5]

Arsenic.—Rice kernel 0.07 mg. per kilo (Jadin and Astruc).[6]

WILD RICE

Zizania aquatica L.

Ger. Tuscarorareis.

This lordly species, known also as Indian, water, or black rice and water oats, grows in the wet marshes of streams and lakes both on the coast and inland. It is often found along creeks on the coast where at high tide it is almost completely submerged. Johnson[7] states that in the province of Ontario, Canada, and neighboring states of the United States the Indian tribes gather the crop in canoes, dry it in the sun, parch it in iron pots, and thresh out the kernels. The limited amount that reaches the market is considered a delicacy.

A southern species (*Z. palustris* L.) has broader leaves, longer but narrower fruit, and lacks commonly the purple color of flowers and leaf markings which is characteristic of the northern species.

Chambliss[8] has conducted extensive experiments on the propagation of both species, chiefly as a food for water fowl.

MACROSCOPIC STRUCTURE.—In both species the female flowers are borne on the upper erect branches of the panicle, the male flower on the lower drooping branches. As in rice, the flowering glume clasps over the palet, enclosing the caryopsis. The *flowering glume* reaches 2 cm. in length, not including the upwardly barbed, twisted *awn* that reaches or exceeds 1.5 cm. It is five-ribbed, with stiff *bristles* along the whole length of the side ribs and toward the end of the middle rib reaching their greatest length (1 mm.) at the base of the awn.

[1] Ann. chim. appl. 1928, **18**, 47.
[2] Cereal Chem. 1929, **6**, 128.
[3] Compt. rend. 1920, **171**, 196.
[4] J. Biol. Chem. 1919, **38**, 191.
[5] Bul. soc. hyg. aliment. 1928, **16**, 457.
[6] Compt. rend. 1912, **155**, 291.
[7] U. S. Daily Consular and Trade Rep. 1912, **15**, 258.
[8] U. S. Dept. Agr. 1922, Circ. **229**.

The *palet* (considered by some as a glume) is two-keeled, two-winged, and taper-pointed.

At full maturity, the caryopsis, or *kernel*, is readily removed by pounding. It is purple-black or brown, narrow (1.5 mm.), cylindrical, up to 2 cm. long, with a *groove* on the side facing the flowering glume extending the whole length, beneath which, extending from the base to about the middle, is the *embryo*. On the palet side it is uniformly rounded with delicate longitudinal striations. The *raphe* is on this side. When removed entire, the caryopsis resembles a piece of small pencil-lead.

It should be noted that whereas in wheat, rye, barley, and oats the *groove* is on the side adjoining the palet, in wild rice it, as well as the embryo, is on the side adjoining the flowering glume.

MICROSCOPIC STRUCTURE.—Pammel [1] has studied the caryopsis in cross section and Mitlacher [2] the flowering glume, palet, and caryopsis in surface view.

Flowering Glume.—In structure this resembles the corresponding part of oats rather than that of rice, the *outer epiderm* consisting of elongated wavy-walled cells alternating with round and twin cells.

Palet.—The structure is much the same as that of the flowering glume except that the wings are less robustly developed and have *epidermal cells* with thinner walls.

Pericarp.—The structure of the pericarp is practically the same as that of its near relative rice, the characters being best brought out in surface preparations. The layers are: (1) *epicarp* with transversely elongated cells with wavy end walls, strikingly developed about the groove, (2) *hypoderm* of transversely elongated cells, (3) *vermiform cells*, also transversely arranged, passing into a spongy parenchyma containing more or less disorganized chlorophyl grains, and (4) numerous narrow *tube cells*.

Spermoderm and Perisperm.—These are seen only after special treatment, as noted under rice, and are then elusive although apparently the same as in rice. The spermoderm shows strongest development on the palet side where spiral and reticulated vessels of the *raphe* are present.

Endosperm.—The *aleurone cells* are thin-walled and show little differentiation from the outer *starch cells*, which latter often contain little or no starch.

The *starch grains*, as in rice, are small (up to 9 μ), polygonal, and occur in large and small aggregates.

[1] Trans. Acad. Sci. of St. Louis 1898, 8, 199.

[2] Z. allg. oesterr. Apoth.-Ver. 1901, 813, 831, 856, 875, 899, 928.

CHIEF STRUCTURAL CHARACTERS.—Kernel narrow, cylindrical, dark-colored, with groove and embryo on same side.

Chaff resembling oats in structure. Fruit elements practically identical with those of rice.

CHEMICAL COMPOSITION.—Samples of parched and sun-dried wild rice from the Lac Courte Oreille Indian Reservation, Wisconsin, analyzed by Woll [1] and 4 samples analyzed by Kennedy [2] contained as follows:

COMPOSITION OF WILD RICE

	Water	Protein	Fat	N-f. ext.	Starch	Soluble carbo-hydrates	Fiber	Ash
	%	%	%	%	%	%	%	%
Woll:								
Parched	9.54	13.00	0.86	74.04	.....	.....	1.12	1.44
Sun-dried	9.99	13.65	0.88	72.68	.....	.....	1.22	1.58
Kennedy:								
I	7.74	13.36	0.46	75.96	65.26	2.98	1.39	1.09
II	7.85	13.97	0.89	74.50	61.69	3.69	1.41	1.38
III	8.93	14.62	0.72	72.62	60.47	2.33	1.94	1.17
IV	7.83	14.40	0.66	74.57	62.03	2.93	1.29	1.25

Kennedy states that wild rice has greater food value than cultivated polished rice, the proteins being of better quality and the content of vitamin B being greater.

Mineral Constituents.—Determinations of inorganic elements by Kennedy [3] yielded the following results, recalculated to oxides:

K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3
%	%	%	%	%	%
0.066	0.086	0.025	0.133	0.971	0.628

[1] Wisconsin Agr. Exp. Sta. 1899, p. 271.
[2] J. Agr. Res. 1924, **27**, 219.
[3] Loc. cit.

CANARY SEED

Phalaris canariensis L.

Fr. Millet long. Sp. Alpiste. Ger. Kanariensamen.

Although best known as a bird food, canary seed is used in southern Europe for the preparation of flour and a textile size. Ribbon grass of our gardens belongs to the same genus.

MACROSCOPIC STRUCTURE.—The inflorescence is in close panicles. At maturity the *spikelet* consists of two boat-shaped, three-nerved, clasping empty glumes (8 mm.), two scale-like *flowering glumes* of a sterile flower about 2 mm. long, and a single flattened *fruit*, 4 to 5 mm. long, entirely hidden within its lustrous, light-buff flowering glume and palet. The chaffy empty glumes and the glumes of the sterile flowers usually remain with the straw on threshing.

The grain and its two envelopes are flattened, with the dorsal and ventral sides at the edges, and short-pointed. Under a lens stiff hairs are seen on both sides of the tip of the five-nerved, shiny, flowering glume and along the back of the palet between the two ribs. So tightly is the fruit held between its glume and palet that it requires some care to remove it entire. Its color is brown. The embryo is on the edge adjacent to the center of the flowering glume, extending from the base nearly to the middle.

MICROSCOPIC STRUCTURE.—Von Höhnel [1] and also Harz [2] give descriptions of the structure of chaff and fruit which differ in some details from the following.

Empty Glumes.—Although present in very small amount in cleaned seed, the structure of the *outer epiderm* warrants special mention. It is remarkable for the large number of round and crescent cells, the former with distinct pits; twin cells, that is, a round and crescent cell together, occur less commonly although a hair and a crescent cell sometimes are adjacent, particularly on the wings, the base of the hair being irregularly elongated or oval. The *hairs* vary from short, thorn-like to long (300 μ) but in both cases with walls so thick that in parts the lumen is not evident at all. On the keel the long cells, which on the body of the grain are longitudinally arranged, extend at an angle to the direction of the rib, ending at the margin in short cells, each with a projecting point.

Flowering Glumes.—In the glumes of the fertile flower all four layers, characteristic of cereal chaff, are represented: (1) *outer epiderm* of

[1] Die Stärke und die Mahlproducte. Kassel u. Berlin, 1882.

[2] Samenkunde. Berlin, 1885, p. 1274.

elongated cells with strongly thickened, sinuous walls, and, both sides of the tip, thick-walled hairs such as occur on the empty glumes, (2) *hypoderm* of thick-walled fibers, (3) *spongy parenchyma* like that of the empty glumes, and (4) *inner epiderm* of straight-walled, elongated, polygonal cells and broad stomata.

So strongly thickened are the walls of the *outer epiderm* that the sinuous character is not evident, the inner bends appearing like pores and the whole like a tissue with thick, straight, porous walls. On heating with sodium hydroxide the sinuous middle lamella is brought out. Von Höhnel appears to have overlooked their sinuous character.

In the glumes of the sterile flower four layers are present only about the center nerve; in other parts only the elongated cells of the *outer epiderm* are conspicuous and these have nearly straight, thin, although pitted, walls. Long *hairs* occur at the tip.

Palet.—The structure is like that of the flowering glume on the middle portion, but the walls on the edges are thinner and *hairs* occur along the keel, which is in the center. The two lateral nerves, which in some cereals have keels, are uniformly rounded.

Pericarp.—All the tissues are more or less brown in color, owing to a substance which impregnates the walls and occurs also in drops. Only three layers are evident: (1) *epicarp* of longitudinally elongated cells with straight walls, (2) *cross cells* of the vermiform type, and (3) *tube cells*. These are easily found in surface preparations but in cross section show little differentiation.

Spermoderm and **Perisperm** are developed only about the raphe.

Endosperm.—The *aleurone cells* are conspicuous both as to walls and contents. The " grains " or enclosures of the network are quite large, reaching 3 μ.

The *starch cells* contain starch aggregates and individual grains of the rice type. Polygonal forms predominate. Most of the grains are less than 6 μ in diameter.

Chief Structural Characters.—Empty glumes keeled, boat-shaped; flowering glume flattened, pointed, lustrous, buff; fruit brown, tightly enveloped by flowering glume and palet.

Outer epiderm of empty glumes with long, round and crescent-shaped cells. Outer epiderm of glume and palet of fertile flower with sinuous and strongly thickened walls. Hairs on envelopes up to 300 μ with thick walls. Epicarp cells elongated, straight-walled; cross cells and tube cells worm-like. All pericarp tissues with brown walls. Starch of rice type.

CHEMICAL COMPOSITION.—An analysis of so-called canary grass grain (*P. intermedia* var. *angusta*) grown in South Carolina, given

in Jenkins and Winton's Compilation,[1] shows the following percentages: water 14.30, protein 13.67, fat 3.52, nitrogen-free extract 37.23, fiber 21.29, and ash 9.99 per cent.

Fat.—N and H [2] found in *P. canariensis* 5.6 per cent of oil (petroleum ether extract) with the following physical and chemical values: refractive index at 25° C. 1.4714, saponification number 184, iodine number 115.5, acid number 20.8, and unsaponifiable matter 1.5 per cent.

Mineral Constituents.—Hanamann [3] found an ash content of 5.19 per cent with the percentages of constituents given below. The high percentage of soda needs confirmation.

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SiO_2
%	%	%	%	%	%	%
4.79	3.04	1.46	3.75	0.27	24.30	61.63

Minor Mineral Constituents. *Zinc.*—Whole seed 15 mg. per kilo, dry basis (Bertrand and Benzon)[4].

OATS

Avena sativa L.

Fr. Avoine. Sp. Avena. It. Vena. Ger. Hafer.

Oats do not appear to have been grown by the ancient inhabitants of the Mediterranean region but, according to De Candolle, originated somewhere between Central Europe and Tartary. They were cultivated by the Swiss lake dwellers and the early Germanic nations.

Warburton,[5] writing before the automobile had displaced the horse to any great extent, stated that in Great Britain and Ireland the acreage of oats was little less than of all other grains, in Germany it exceeded the combined acreage of wheat and barley and was second only to rye, and in the United States it was second only to maize and wheat.

Although preeminently a food for cattle and especially horses, the heart of the grain in the form of oatmeal and rolled oats is a highly nutritious human food.

Two types distinguished by their inflorescence are in cultivation: (1) the panicled and (2) the banner or horse mane. Both are really in

[1] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11.**

[2] Z. angew. Chem. 1916, **29,** I, 337.

[3] Wittstein: Vierteljahrschr. **12,** 517.

[4] Bul. soc. hyg. aliment. 1928, **16,** 457.

[5] U. S. Dept. Agr. 1910, Farm. Bul. **424.**

panicles but in the former they are loose, whereas in the latter the spikelets are sharply turned to one side as suggested by the names. Banner oats have been given a specific name, *A. orientalis* Schreb., but this type is generally regarded as merely a variety.

Naked oats are not commonly cultivated but are of interest as showing that the chaffy condition is not universal, thus placing oats in the same category with wheat and barley, which also have both naked and chaffy varieties.

Wild oats (*A. fatua* L.), thought by some to be the parent of cultivated varieties, are a common weed in grain fields and occur in screenings of wheat and other cereals.

MACROSCOPIC STRUCTURE (Figs. 70 and 71).—Normally the spikelet is two-flowered. The *empty glumes* (EG^1 and EG^2) are large,

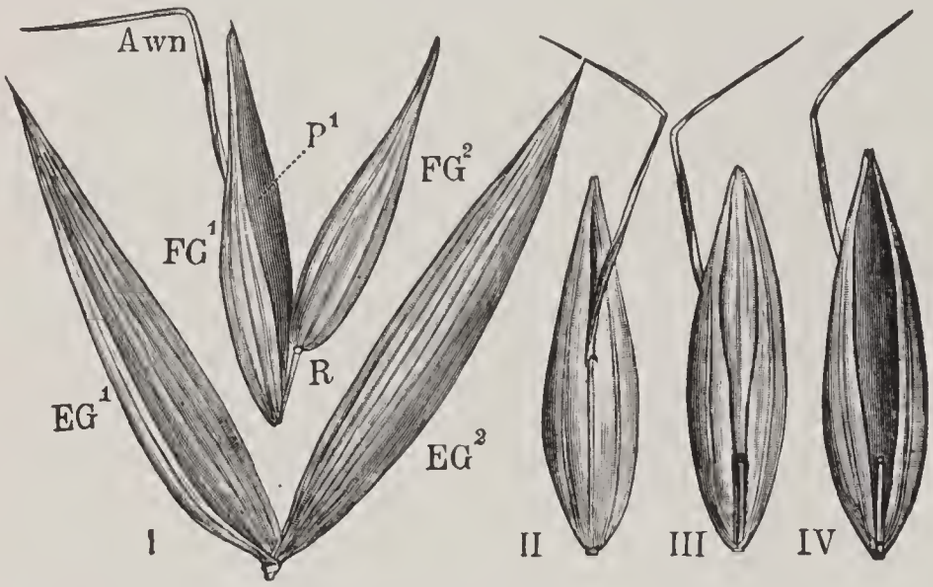


FIG. 70.—Oats. I two-fruited spikelet entire. EG^1 and EG^2 empty glumes; FG^1 flowering glume and P^1 palet enclosing lower fruit; *Awn* awn of flowering glume; FG^2 flowering glume of upper fruit concealing kernel and palet; *R* rachilla. II dorsal side of lower fruit showing flowering glume with three veins and awn. III ventral side of lower fruit showing edges of flowering glume clasping upper fruit. IV same as III but upper fruit removed. ×2. (A.L.W.)

thin, pointed, several-nerved, and awned or awnless. They usually remain with the straw on threshing.

Both flowers are usually fertile but the lower fruit may be more robustly developed than the upper. The *lower fruit* is tightly clasped by the seven-nerved *flowering glume* (FG^1) and the two-keeled *palet* (P^1), the former often being awned. The *upper fruit*, tightly clasped by its own *flowering glume* (FG^2) and *palet* (P^2), is borne on a stem or *rachilla* (*R*) and is commonly held closely against the lower fruit by the sides of the flowering glume of the latter which are so extended as to cover all but the upper portion of the palet, although it may have come loose from this embrace on becoming detached.

Fig. 70, III, shows the rachilla and dorsal side of the upper fruit with all but a portion of the flowering glume hidden by the overlapping flowering glume of the lower fruit; IV shows the lower fruit after removal of the upper. The arrangement of the complete double fruit or grain with the chaff is brought out by Fig. 71, which also shows the concavity of the lower fruit into which the upper fits, the interesting manner in which the flowering glumes and palets clasp the kernels, also the general structure of the kernels. The arrangement in the groove is like that of wheat and rye and not barley.

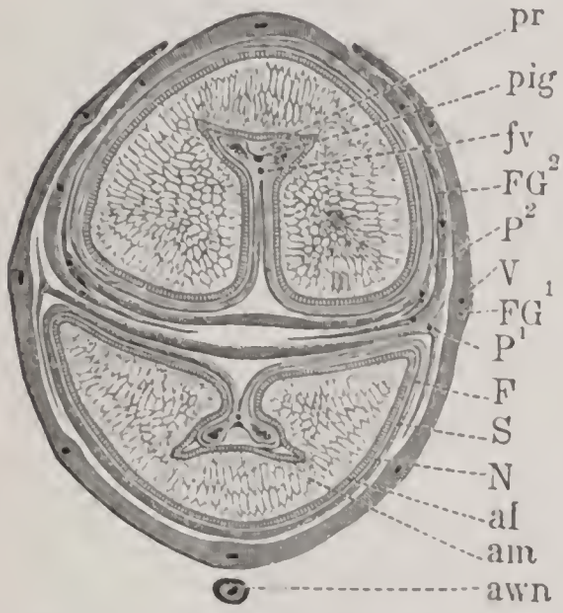


Fig. 71.—Oats. Spikelet with two fruits in cross section. FG^1 flowering glume and P^1 palet of lower fruit; FG^2 flowering glume and P^2 palet of upper fruit; *awn* awn of lower fruit; *V* vein; *F* (gray) pericarp; *S* (black line) spermoderm broadening into *pig* pigment strand adjoining *fv* bundle; *N* (white line) perisperm broadening into *pr* perisperm strand; *al* aleurone layer; *am* starch cells. ×15. (A. L.W.)

Separated from the chaff the *kernels* are seen to be clothed with hairs which, being longer than in wheat and not confined to the end of the kernel, give them a more downy appearance; furthermore the kernel is longer and narrower than the wheat kernel.

MICROSCOPIC STRUCTURE.—Oats are sharply distinguished from chaffy wheats and barleys not only by the structure of the fruit proper (caryopsis) but by the structure of the chaff itself, which to the naked eye in fragments of considerable size is very similar. The distinction between oat chaff and rice chaff (commonly known as oat hulls and rice hulls) is also striking notwithstanding the close resemblance in microsocopic characters of the endosperm.

Flowering Glume. (Fig. 72, *G*; Fig. 73).—On the dorsal portion, except at the edges and tip, there are four layers, as in barley and other chaffy cereals: (1) *outer epiderm* (*aep*, aep^2) with long cells, round cells, and twin cells, the long cells having thick zigzag walls, (2) *sclerenchyma fibers* (f, f^1, f^2), both thick- and thin-walled, several cells deep, (3) *spongy parenchyma* (p, p^1), with extraordinarily large intercellular spaces, thus forming long arms on the cells themselves which may be described as hide-shaped, and (4) *inner epiderm* (*iep*) consisting of longitudinally elongated cells with straight walls and stomata.

The *epidermal cells* in cross section are somewhat elongated transversely whereas the *fibers* are oval, the radial diameter being the longer. In cross section cuticular warts are seen which appear to belong over the round cells. In surface view these are indistinct because of the trans-

parency of the silicified cuticle. Surface preparations (Fig. 73, f^1) also show that some of the fibers are notched or wavy in outline, conforming to the outline of the inner walls of the epiderm.

The *spongy parenchyma* cells are described by Moeller [1] as star-shaped, thus distinguishing them from the quadrilateral cells of barley. Emmerling [2] employs this important distinction in the examination of chaffy products such as brewery and distillery grains. A study of the cells brings out a simple fundamental detail of structure to which the

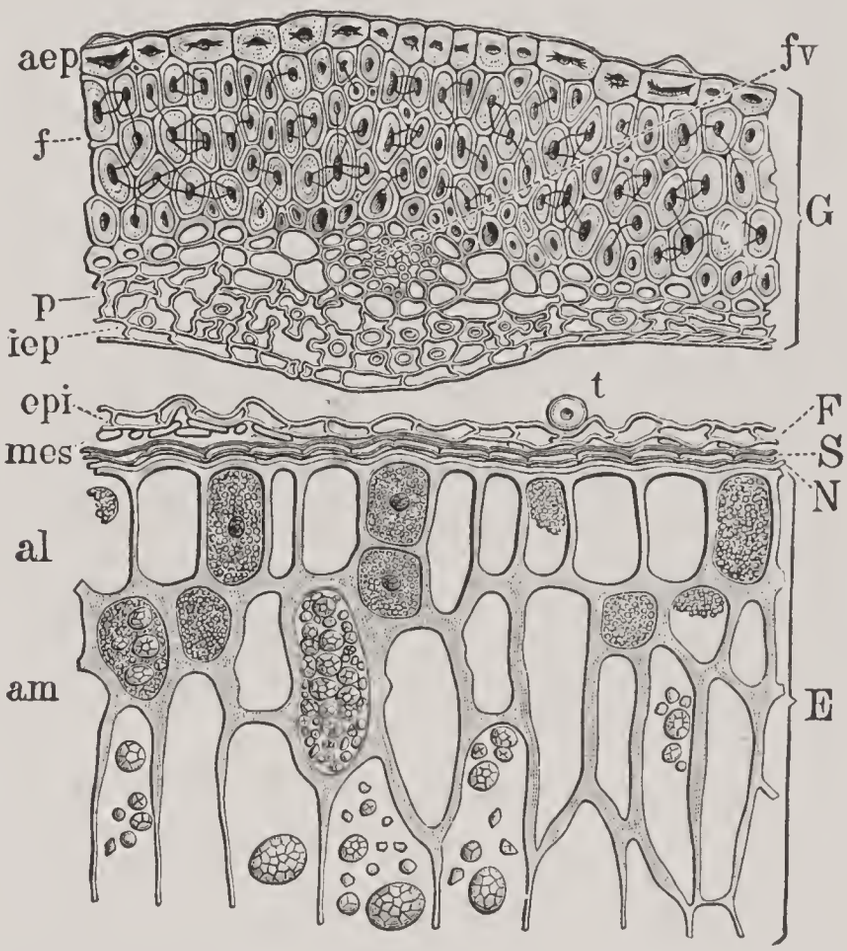


FIG. 72.—Oats. Kernel and chaff in cross section through central dorsal side. *G* flowering glume: *aep* outer epiderm with cuticular warts, *f* fiber layer, *p* spongy parenchyma with *fv* bundle, *iep* inner epiderm. *F* pericarp: *epi* epicarp with *t* hair, *mes* spongy parenchyma. *S* spermoderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *am* starch cells. ×160. (A.L.W.)

difference in form is due, namely, the size of the intercellular spaces, which in oats are large and in barley small. Small intercellular spaces do not destroy the general quadrilateral form of the cells; large ones give them a branching form which may be compared to animal hides. A star-shaped form suggests radiation from a common center and pointed ends, neither of which these cells possess. Near the fibro-

[1] Mikroskopie Nahr.-Genussm. Berlin, 1 Aufl. 1886, p. 157.
[2] Landw. Vers.-Stat. 1898, **50**, 1.

vascular bundles (*f.*) of the nerves the intercellular spaces are small and consequently the form of the cells is nearly quadrilateral.

Along the marginal nerves, particularly toward the tip, the long cells (Fig. 73, *aep*[1]) are thinner-walled, although more or less wavy in outline, and are interspersed with stomata and broad, short, conical hairs. The fiber and spongy parenchyma layers are reduced in thickness or vanish entirely at the margins and tip.

Awn (Fig. 74).—Owing to their dark color, bleaching of preparations with Javelle water is necessary. Cross sections are usually unsatisfactory on account of the twisted nature of the awn.

The tissues are a continuation of the three outer tissue zones of the flowering glume and are as follows: (1) *epiderm* remarkable for its saw-

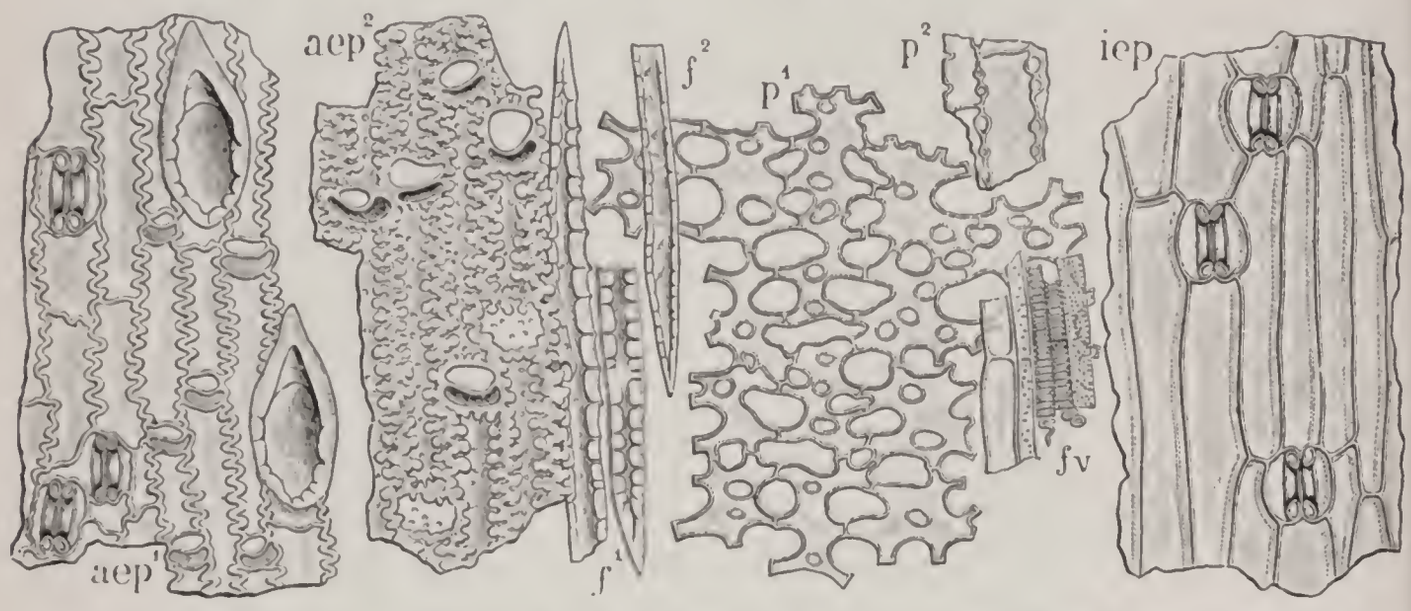


FIG. 73.—Oats. Elements of flowering glume in surface view. *aep*[1] outer epiderm along marginal vein near apex showing long cells, twin cells, stomata, and conical hairs. Following from central dorsal side: *aep*[2] outer epiderm with long cells, twin cells, and round cells; *f*[1] and *f*[2] thick- and thin-walled fibers adjoining outer epiderm; *p*[1] spongy parenchyma; *fv* fibro-vascular bundle; *p*[2] spongy parenchyma adjoining bundle; *iep* inner epiderm. ×160. (A.L.W.)

tooth hairs (*t*), attached for two-thirds their length, distributed among the long cells, round cells, and twin cells between bands with stomata (*sto*), (2) *sclerenchyma fibers* (*f*) with truncated ends, (3) *spongy parenchyma* (*p*) with very small quadrilateral cells and (4) a *fibro-vascular bundle* (*fv*) joining that of the mid-vein.

The *epiderm*, on the dorsal side at the base, has the same structure as the epiderm of the flowering glume of which it is a continuation, consisting of long cells, round cells, and twin cells, flanked by bands with stomata. This general arrangement continues upward on the awn, but a considerable number of the long cells are replaced by saw-tooth *hairs* which are morphologically long cells, the upper ends of which are extended out from the surface into points.

The *sclerenchyma fibers* at the base of the awn are broad (up to 30 μ or more), but further upward on the awn they are narrow and, as obtained by maceration with sodium hydroxide, resemble bundles of quills. Both the broad and the narrow forms are characterized by the truncated ends and general rectangular shape.

Spongy parenchyma is noticeable only beneath the stomata where the

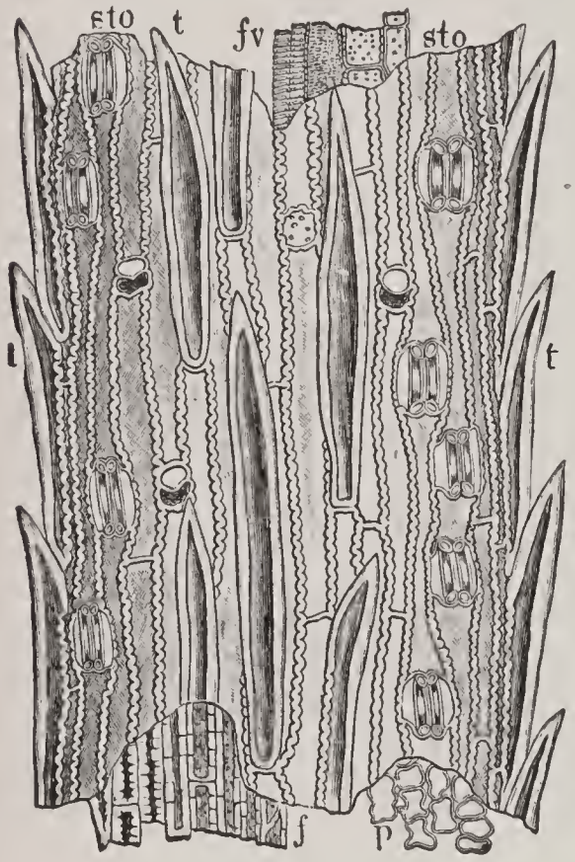


Fig. 74.

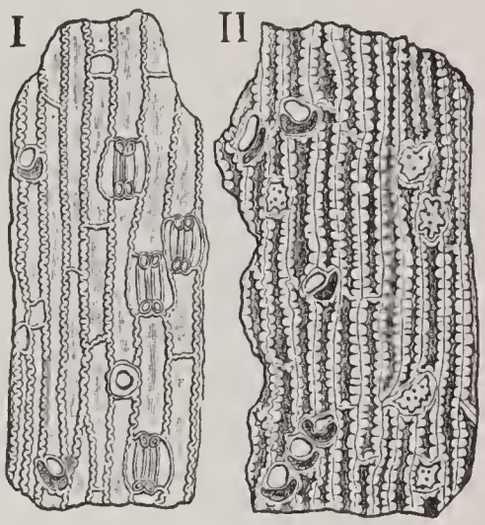


Fig. 75.

Fig. 74.—Oats. Awn, central portion, in surface view. Epiderm consists of long cells, twin cells, round cells, *t* stiff hairs, and *sto* stomata; *f* blunt hypoderm fibers; *p* spongy parenchyma; *fv* fibro-vascular bundle. ×160. (A.L.W.)

Fig. 75.—Oats. Epiderm of rachilla in surface view. I side away from ventral side and palet of lower fruit. II side facing ventral side and palet of lower fruit. ×160. (A.L.W.)

cells are small and quadrilateral, with small intercellular spaces, being not unlike the spongy parenchyma of barley chaff.

Rachilla.—After the upper fruit breaks away from the lower the rachilla ordinarily remains attached to the lower fruit lying against its ventral side. It has the usual structure of the straw.

The *epiderm* on the side away from the lower fruit (Fig. 75, I) consists of long cells with sinuous walls, round cells, twin cells and stomata occurring in bands. Some of the round cells are obviously hair scars.

On the side facing the lower fruit, stomata are absent, and the long cells are so deeply sinuous that they appear porous (Fig. 75, II).

Palet (Figs. 76 and 77).—Although resembling the flowering glume in general structure, the palet differs in a number of respects: (1) each keel has a *comb edge of stiff hairs* (Fig. 76), (2) *stomata* occur in longitudinal bands both sides of the keels, (3) the *cell walls* on the wings are thinner than on the main palet between the keels, and (4) short but stout *hooked hairs* form a *saw-edge* (Fig. 77) on the margins near the tip and similar hairs occur on the surface near the margins.

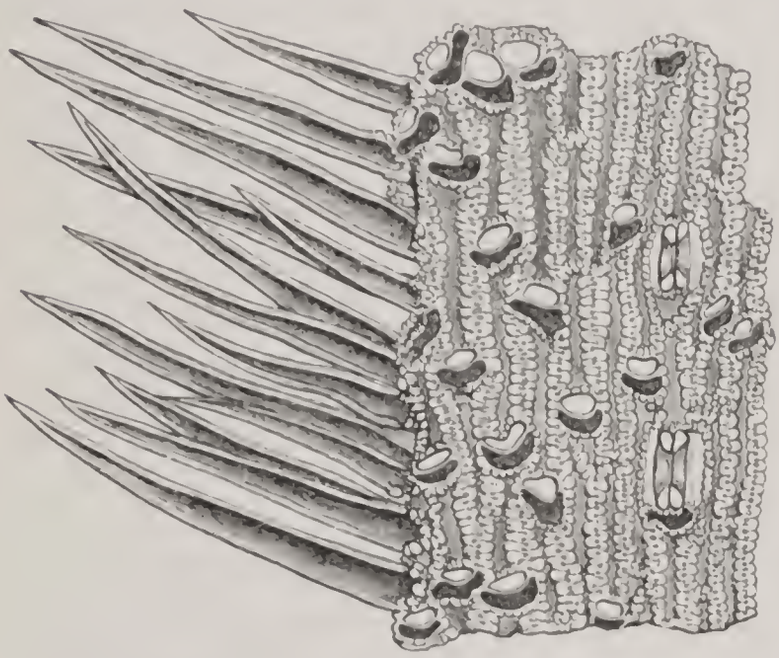


Fig. 76.—Oats. Outer epiderm of palet at keel, midway between base and apex, in surface view, showing long cells, twin cells, stomata, and saw edge of stiff hairs. ×160. (A.L.W.)

The long cells on the main body of the palet are not only deeply sinuous but much thickened and distorted. All gradations through cells with thinner but sinuous walls to elongated thin- but straight-walled cells occur between the center of the palet and the margins of its wings.

Pericarp (Figs. 72, *F*; Fig. 78).—Only two layers are differentiated: (1) *epicarp* (*epi*) of delicate, porous, longitudinally elongated (even at the apex) cells with here and there *hairs* (*t*) up to 2000 μ in length, the longest being broadest in the middle and narrowed to both the base and the apex, and (2) *hypoderm* (*mes*) consisting of a rather indefinite layer of thin-walled, branching hyphæ-like cells, in parts resembling the vermiform cross cells of maize and rice and in other parts the tube cells of various cereals.

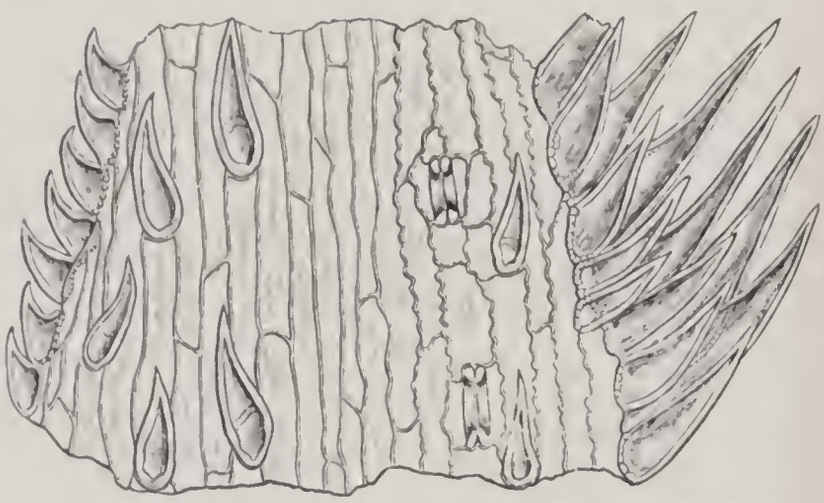


Fig. 77.—Oats. Outer epiderm of wing of palet near tip, in surface view, showing at right saw edge of curved hairs over keel, at left marginal row of hooked hairs, and on surface scattered hairs and two stomata. ×160. (A.L.W.)

The *hairs* (Fig. 79) vary greatly in length and breadth of lumen, but most of them may be grouped in two classes: (1) *long hairs* with lumen

narrower than the walls, tapering toward both ends, the base, however, being more or less globular and broader than the portion above it and (2) *short hairs* with lumen broader than the walls, tapering from the base to the apex. Both forms occur singly or in twins and triplets, long and short forms often occurring together. When a kernel is scraped, as in milling, the hairs often break near the base at their narrowest part and the detached hairs appear almost as pointed at the lower end as at the upper.

Under the head of *hypoderm* is grouped the curious complex of spongy parenchyma, forming the pericarp below the epicarp. This layer, as well as the spermoderm and perisperm, is best brought out in cross

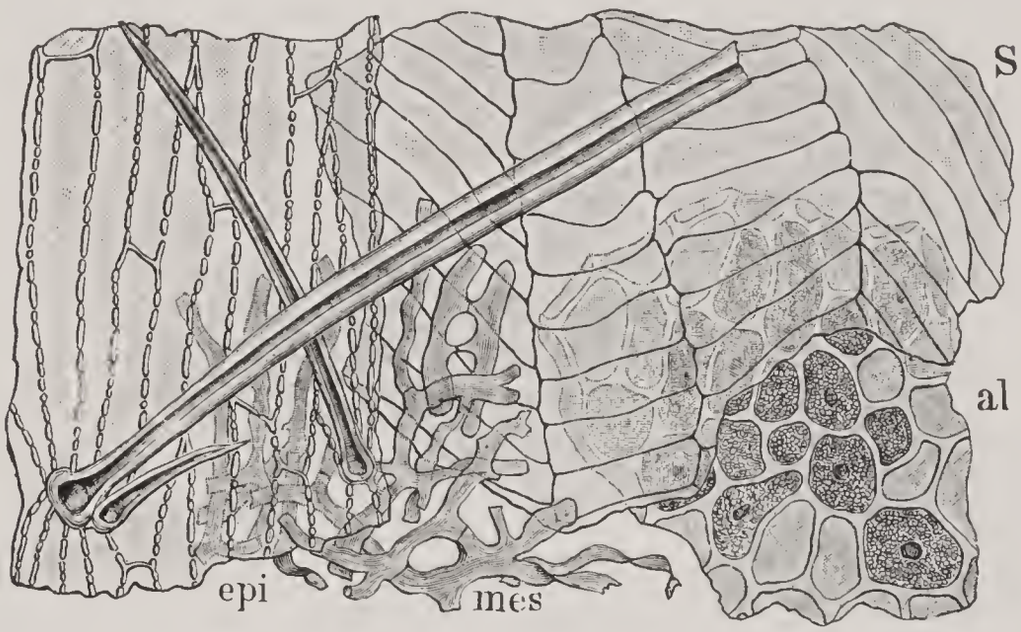


FIG. 78.—Oats. Bran coats from central dorsal side in surface view. *epi* epicarp; *mes* spongy parenchyma; *S* spermoderm; *al* aleurone cells. ×160. (A.L.W.)

section by warming with sodium hydroxide, acidifying with acetic acid, and mounting in chlorzinc iodine which stains the hypoderm cells blue. Surface preparations are obtained by warming whole kernels in sodium hydroxide, plunging in acetic acid, scraping, and mounting in chlorzinc iodine.

Spermoderm (Figs. 72 and 78, *S*).—Only one distinct layer is evident. As seen in surface preparations, mounted in chlorzinc iodine as above described, this consists of transversely elongated cells with delicate walls, arranged side by side in rows, often in herringbone fashion. Traces of another layer occur in parts but there is no definite tissue extending over the whole grain. The definite layer and the traces of another layer both stain deep yellow or brown-yellow with chlorzinc iodine, as does also the rather thick cuticle lying outside of the definite layer and belonging obviously to it, and the thin cuticle inside of the indistinct layer separating it from the perisperm.

Some authors have mistaken the definite layer for cross cells of the pericarp, but if these cells are followed around a cross section it may be seen that they belong with the pigment strand and form a true spermoderm layer. The traces of an inner layer, being bounded by a cuticle, cannot belong with the perisperm.

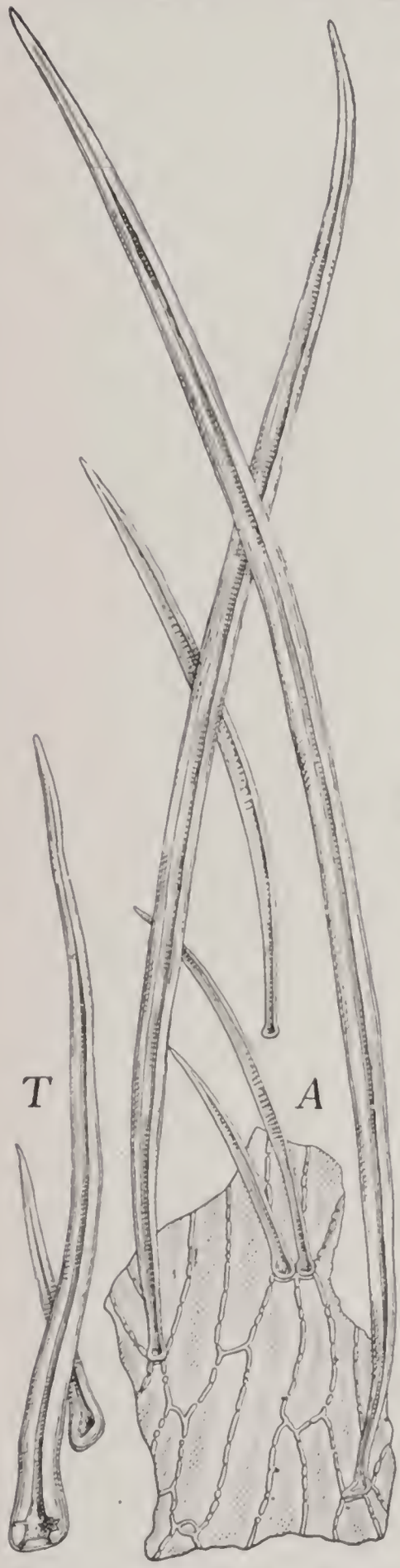


Fig. 79.—Oat hairs (*A*); Wheat hairs (*T*). ×160. (A.L.W.)

Perisperm (Fig. 72, *N*).—This layer is evident in cross section as a narrow hyaline band which, followed about the kernel, is seen to merge with the perisperm strand. No cellular structure is evident in surface view, even in chlorzinc iodine mounts, which is not surprising since the band is much thinner than in wheat.

Endosperm (Fig. 72, *E*).—The *aleurone cells* (Figs. 72 and 78, *al*) are only slightly smaller than those of wheat, but their walls are thinner. They extend around the kernel into the groove and about the Y seen in cross section at the bottom of the groove just as in wheat. Here and there some of the cells obviously belonging to the aleurone layer contain starch grains. On the other hand, some of the starch cells contain protein contents partly or entirely displacing the starch. There is, in fact, as well as in wheat and other cereals, no sharp demarcation between aleurone and starch cells.

The *starch cells* (Fig. 72, *am*) are characterized by their thick walls in the first one or two layers. This is evidently due to swelling.

Oat starch, like rice starch, has small polygonal grains up to about 10 μ in diameter which are united into aggregates of from two to some scores or even a hundred or more individuals. The occurrence of spindle-shaped grains, which from their form do not appear ever to have been members of an aggregate, furnishes a rather uncertain distinction from rice starch.

No distinct hilum is evident in the starch grains, although with polarized light crosses are formed through the center of the grains.

CHIEF STRUCTURAL CHARACTERS.—Enveloped in the chaff, grain slender (barley broader and shorter), uniformly rounded (barley ribbed), and gradually tapering (barley beaked at the base). Lower grain of spikelet concave on ventral side (convex in barley). Kernel grooved, hairy at apex (as in wheat group).

Chaff elements: (1) comb-edge of hairs on palet keels (barley smooth), (2) saw-edge of hairs on margin of palet (barley smooth), (3) stomata numerous (in barley absent), (4) spongy parenchyma cells hide-shaped (barley quadrilateral), (5) lodicules with long silky hairs absent (present in barley), and (6) tip of rachilla smooth (barley and wild oats bristly). Epicarp with long hairs (2000 μ), narrowed at base (wheat group broad at base); mesocarp of spongy parenchyma corresponding to cross cells and tube cells of other cereals. Starch grains of rice type.

MICROSCOPY OF OAT PRODUCTS.—Whole Oats, ground or unground, alone or mixed, because of their chaffy nature, can be eaten only by animals. The characters and distinctions from other cereals are noted in the foregoing section.

Rolled Oats and **Oat Meal,** prepared by removal of the chaff with or without steaming or cooking, rank among the most nutritious and palatable of human cereal foods. All the elements of the pericarp, spermoderm, perisperm, endosperm, and embryo are present. The condition of the starch grains depends on the degree of cooking. Occasional fragments of the chaff, detected in eating, may be present. The detached epicarp hairs, seemingly pointed at both ends, are characteristic.

Oat Hulls and similar by-products, obtained in the manufacture of oat meal and rolled oats, contain not only the chaff but also small and imperfect kernels, usually the top kernels of spikelets. The macroscopic characters of unground hulls usually suffice for identification, but the histological structure of ground hulls furnishes the only criterion.

CHEMICAL COMPOSITION.—Analyses of whole oats are of interest chiefly in cattle feeding. Prior to 1892 only a few analyses of American oats were recorded and these are not representative. Wiley and co-workers [1] have reported on 72 samples of oats grown in the United States and Canada and exhibited at the World's Fair at Chicago. Chamberlain [2] made an extensive study of American and European grown oats. A summary of these analyses made at the Bureau of Chemistry follows:

[1] U. S. Dept. Agr., Bur. Chem. 1895, Bul. **49**, 29.
[2] Ibid. 1909, Bul. **120**.

Composition of Whole Oats (Bureau of Chemistry)

	Samples	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Wiley (1893):	72						
Min.		7.87	9.10	0.93	53.70	8.52	2.47
Max.		13.02	15.05	6.14	61.98	16.65	4.37
Aver.		9.96	12.07	4.42	58.28	11.92	3.35
Chamberlain (1903–5):							
United States:	242						
Min.		5.00	8.75	1.79	59.06	8.46	2.85
Max.		10.72	19.75	7.47	72.91	20.08	5.37
Aver.		71.82	13.76	4.38	66.29	12.20	3.96
Europe:	54						
Aver.		8.31	11.63	5.86	67.91	10.80	3.61
Hull-less:	2						
Aver.		8.04	18.37	6.26	70.05	2.80	2.51

Oat Products.—The average composition of *rolled oats*, *oat bran*, and *oat hulls* is shown in the following table furnished by Carl Miner, of the Miner Laboratories, Chicago:

Composition of Oat Products (Miner)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Rolled oats	8.40	16.04	6.79	65.57	1.45	1.75
Oat bran	6.50	19.30	7.10	59.90	4.60	2.60
Oat hulls	6.75	3.85	1.40	48.75	33.45	5.80

The figures for rolled oats are the average of a large number of factory tests made during a single season. The oat bran is the true bran of oat groats from which the starch has been removed by washing, which may have removed water-soluble constituents to some extent. It is not a commercial product.

Hulled Oats and Oat Hulls.—These products represent the extremes—the first, a highly nutritious human food, the second, a waste product of little more value in feeding than straw but now invaluable as the raw material for the manufacture of furfural. Richardson [1] in the eighties

[1] U. S. Dept. Agr., Div. Chem. Bul. 9.

analyzed both. The percentages of hulled oats in the whole grain ranged from 55.37 to 79.28 per cent. The average composition of the hulled oats (179 samples) and the hulls (100 samples) was, respectively: water 6.93 and 5.22, protein 14.31 and 2.48, fat 8.14 and —, nitrogen-free extract 67.09 and 68.83 (including fat), fiber 1.38 and 17.88, and ash 2.15 and 5.59 per cent. In some instances the protein of the hulled oats reached nearly 20 per cent and the fat over 11 per cent. The minimum protein was over 9 per cent and the minimum fat over 6 per cent.

Relation of Physical Characters to Composition.—Berry [1] classified 700 proximate analyses of oats according to the color and size of the grain and their protein and fat content. Black oats with large kernels and thin husks were the richest of the cultivated varieties, and wild oats were even richer. The smaller kernels were richer in fat but slightly poorer in protein. During the first half of the period of development the fat increases rapidly, then remains stationary; the protein increases throughout the period.

Influence of Fertilization on Composition.—Of the numerous experiments, only two need here be cited.

Woods and Gibson[2] have shown that application of commercial fertilizers materially increases the protein content of the grain. This was particularly marked when the fertilizer was nitrogenous, nitrate of soda increasing the protein content 2.59 per cent; sulphate of ammonia, 1.03 per cent; and dried blood, 0.76 per cent, on the water-free basis. Nitrogen-free extract and fat were increased to a lesser extent, and the fiber was decreased.

Tretiakov [3] raised the protein content of oats from 11.38 to 12.81 per cent by fertilizing with stable manure.

Influence of Soil and Climate on Composition.—Whether due to one or both causes, Chamberlain (see table above), in an extensive investigation, has demonstrated that domestic oats are distinctly higher in protein but somewhat lower in fat than the European grown grain; further, that European varieties on American soil acquire the characteristics of the domestic.

Proteins.—The true proteins of oats are not so well understood as those of the maize and wheat groups.

J. P. Norton [4] extracted a prolamine with weak alcohol which he named *glutin*. Kreusler [5] obtained the same substance, although his and Ritthausen's oat gliadin appears to have suffered change.

[1] Brit. Assn. Adv. Sci. 1912, M.
[2] Connecticut Storrs Agr. Exp. Sta. Rep. 1890, p. 93.
[3] Trudy Poltav. Selsk. Khoz. Opytn. Stantsii, 1913, p. 28.
[4] Am. J. Sci. Arts. (2) 1845, **3**, 330; 1848, **5**, 22.
[5] J. prak. Chem. 1869, **107**, 17.

Osborne [1] prepared and analyzed this gliadin (prolamine) in a state of probable purity.

A globulin or salt-soluble protein, *avenalin*, was obtained by Osborne in crystalline form. He states that the gliadin forms about 1.25 per cent and the avenalin about 1.5 per cent of the grain, the remainder of the protein, excepting extremely small amounts of albumin and proteose, being the "insoluble protein," that is, the protein insoluble in water, alcohol, and salt solution but largely soluble in dilute alkali.

The *insoluble protein*, if it consists of a single individual, is a glutelin (*avenin*), analogous to the glutenin of wheat. In oats of average composition, with 11.80 per cent of total protein, 1.25 per cent of gliadin, and 1.50 per cent of avenalin, there would be 9.05 per cent of proteins to be accounted for. How much of this is avenin is yet to be determined.

Csonka [2] has extended our knowledge of the insoluble proteins by precipitating the *glutelin* from a 0.2 per cent sodium hydroxide extract by adding ammonium sulphate to 0.018 saturation. Its isoelectric point is about *p*H 6.45. No other glutelin was found in oats.

Lüers and Siegert [3] have isolated five proteins from oats: (1) an albumin, (2) a globulin soluble in 10 per cent cold salt solution, (3) a globulin soluble in 10 per cent salt solution at 65° C., (4) a prolamine, and (5) a glutelin precipitated from a 0.2 per cent potassium hydroxide extract by acetic acid. The prolamine resembles gliadin and hordein but has a higher cystine content (3.7 per cent).

Ultimate Composition.—Osborne's analyses [4] of the three chief proteins, which he obtained sufficiently pure to warrant study, follow:

Ultimate Composition of Oat Proteins (Osborne)

	Avenalin (globulin)	Gliadin (glutin of Norton)	Avenin (glutelin)
	%	%	%
Carbon	52.19	53.01	53.56
Hydrogen	7.00	6.91	7.09
Nitrogen	17.86	16.43	16.20
Sulphur	0.65	2.26	0.90
Oxygen	22.30	21.39	22.25
	100.00	100.00	100.00

[1] Am. Chem. J. 1891, **13**, 327, 385; 1892, **14**, 212.

[2] J. Biol. Chem. 1927, **75**, 189.

[3] Biochem. Z. 1924, **144**, 467.

[4] Loc. cit.

So-called "secondary proteins" were also prepared and analyzed, but he believed them to be alteration products.

Csonka [1] found the composition of oat glutelin to be as follows:

	%
Carbon	52.60
Hydrogen	6.56
Nitrogen	17.53
Sulphur	0.81
Phosphorus	trace
Ash	0.28

Amino Acids of Oat Proteins.—A little more than half of the total amount of amino acids of the avenin of oats has been accounted for by Abderhalden and Hämäläinen [2] as follows:

Amino Acids of Avenin (Abderhalden and Hämäläinen)

	%
Glycocoll	1.0
Alanine	2.5
Valine	1.8
Leucine	15.0
Aspartic acid	4.0
Glutamic acid	18.4
Tyrosine	1.5
Phenylalanine	3.2
Proline	5 4
	52.8

By Van Slyke's method, Csonka [3] obtained from water- and ash-free oat glutelin: cystine 2.99, arginine 8.33, lysine 4.98, histidine 2.26, and ammonia 16.37 per cent. By combining these figures with those of Abderhalden and Hämäläinen the total reaches 87.7 per cent. This calculation may not, however, be justified in view of the possible difference in the preparations.

Jones, Gersdorff, and Moeller [4] obtained in oat gliadin 3.48 per cent of cystine but no tryptophane.

Nitrogen Distribution in Oat Glutelin.—The results tabulated on the following page are in percentages of the total nitrogen.

Nitrogen Distribution in Oats and Oat Products.—The nitrogen distribution in the oat kernel by Van Slyke's method, as determined by

[1] Loc. cit.

[2] Z. physiol. Chem. 1907, **52**, 515.

[3] Loc. cit.

[4] J. Biol. Chem. 1924, **62**, 183.

	Lüers and Siegert	Csonka
	%	%
Humin N	2.89	1.42
Cystine N	1.52	1.99
Arginine N	14.43	15.30
Lysine N	4.39	5.45
Histidine N	7.24	3.49
Amino N of filtrate	52.35	54.71
Non-amino N of filtrate	4.08	2.32
Amide N	12.19	13.46
Total	99.09	98.14

Hamilton, Nevens, and Grindley,[1] was found to be as follows: amide nitrogen 11.42, humin nitrogen 5.53, cystine nitrogen 0.94, arginine nitrogen 11.65, histidine nitrogen 5.80, lysine nitrogen 2.84, mono-amino nitrogen 42.14, non-amino nitrogen 3.86, ether-soluble nitrogen 0.57, alcohol-soluble nitrogen 1.22, non-protein nitrogen soluble in trichloracetic acid in filtrate from colloidal iron 11.13, nitrogen lost in method of analysis 1.90; total nitrogen 99.00; total basic nitrogen 21.23 per cent.

Nollau[2] found much more cystine, histidine, and non-amino nitrogen than the above but no lysine nitrogen except in sprouted oats, which contained 0.7 per cent.

Free Amino Acids, Acid Amides, and Polypeptides.—Determinations by Jodidi,[3] made in the water extract, appear in the table below.

Fat (Ether Extract).—Oat oil appears to have been ignored by oil chemists, doubtless because there has been no reason for its commercial preparation. It is, however, of interest to the agricultural chemist and nutritionist as a constituent of the kernel but not for removal.

Physical and Chemical Values.—Stellwaag[4] and Paul[5] obtained similar figures in the examination of the extracted fat. Paul employed petroleum ether as the solvent under pressure and removed the lecithin from the extract. The principal results of the two analysts appear below.

Paul also reports the following values of the fatty acids: acid value

[1] J. Biol. Chem. 1921, **43**, 249.
[2] J. Biol. Chem. 1915, **21**, 611.
[3] J. Frank. Inst. 1924, **198**, 201; J. Agr. Res. 1925, **30**, 989.
[4] Landw. Vers.-Stat. 1890, **37**, 135.
[5] Analyst, 1921, **46**, 238.

Distribution of Non-protein Nitrogen in Oats (Jodidi)

	Acid amide N	Amino acid N	Peptide N
	%	%	%
In oven-dried oats:			
Swedish Select	0.051	0.064	0.106
Victory	0.029	0.040	0.073
Iowar	0.046	0.057	0.084
Winter Turf	0.027	0.025	0.032
In total nitrogen:			
Swedish Select	1.95	2.48	4.10
Victory	1.45	2.02	3.63
Iowar	1.93	2.35	3.49
Winter Turf	1.80	1.65	2.15

196.6, mean molecular weight 284.8, iodine number 127.1, melting point 27.5° C., and refractive index 1.4635.

Values of Oat Oil

	Sp. gr. 15°/15°	Ref. index 40° C.	Melting point	Saponification No.	Iodine No. (Wijs)	Acid, free as oleic	Neutral fat	Fatty acids insol.	Unsap. matter
			° C.				%		%
Stellwaag	.....	.....	20	192.4	.....	35.4	59.2	92.8	2.65
Paul	0.925	1.4701	8	189.8	114.2	34.7	64.0	93.6	1.30

Carbohydrates.—*Sugar* and *dextrin* in 25 analyses reported by Moser and co-workers [1] varied from 2.04 to 5.27 per cent, the remainder of the nitrogen-free extract being calculated as starch.

In rolled oats of average composition Carl Miner reports 52.1 per cent of *starch* and 3.8 per cent of *pentosans*. In oat bran the percentage of starch was 45.2.

Porphyratin, according to Schumm and Mertens [2] is present in oats. It is believed to be identical with animal hematin. Porphyrin, prepared from it, corresponds with hemateric acid.

Phosphorus-Organic Compounds. *Lecithin.*—No result available.

Phytin.—From the oat kernel Anderson [3] extracted organic phosphoric acid which formed with barium two compounds, one crystalline, such as was obtained from cottonseed meal, which he regards as a salt

[1] Landw. Vers.-Stat. 1882, **27**, 209.
[2] Z. physiol. Chem. 1926, **158**, 77.
[3] J. Biol. Chem. 1914, **17**, 151.

of inosite hexaphosphoric acid, the other amorphous and apparently the same as the phytin of wheat bran.

Rather [1] believes that the phytin is inosite pentaphosphoric acid, $C_6H_6(OH)(H_2PO_4)_5$. He found that the phosphorus in this compound forms 81 per cent of the total phosphorus, the remainder being: inorganic phosphoric acid 8 per cent and other forms of organic combination 11 per cent.

Determination of phytin by Averill and King [2] yielded 0.77 per cent, calculated as inosite hexaphosphoric acid.

Lindenbaum[3] obtained from oat flour the following amounts of phosphoric acid (P_2O_5): phytic 0.573, mineral 0.084, and in other organic combination 0.133 per cent, thus confirming the results of the foregoing investigators. The optimum reaction for the enzyme converting the organic into inorganic phosphoric acid was *p*H 4.9 to 5.75.

Nucleic Acid.—See Wheat.

Enzymes. *Amylase.*—Baker and Hulton [4] found that the amylase from oats dissolves starch paste slowly and from potato starch forms at 50° C. only crystalline maltose, suggesting that the starch molecule consists of condensed maltose residues. The amylase from germinated oats, on the other hand, dissolves starch paste rapidly, forming dextrin—a substance related to malto-dextrin—and what appeared to be maltose.

Maltase is present in only small amount, according to Wierzchowski.[5]

Protease was detected but not determined by Giesen.[6]

Mineral Constituents.—Early analyses of the ash of oats are quite as accurate as some made recently, excepting the figures for iron which are doubtless too high. The averages of analyses made by Way and Ogston [7] and by Wolff [8] are respectively as follows:

Composition of Oat Ash

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
W. and O.	16.6	2.6	3.8	7.0	0.5	22.6	1.6	44.9	0.6
Wolff	16.4	2.2	3.7	7.1	0.7	23.0	1.4	44.3	0.6

[1] J. Am. Chem. Soc. 1918, **40**, 523; Arkansas Agr. Exp. Sta. Bul. **138.**

[2] J. Am. Chem. Soc. 1926, **43**, 724.

[3] Bul. Acad. Polonaise, 1926B, 1041.

[4] J. Chem. Soc. **1929**, 1655.

[5] Biochem. Z. 1913, **57**, 125.

[6] Inaug. Dis. Bern, 1909.

[7] Liebig: Chemie in ihre Anwendung auf Agricultur, 1865, **1.**

[8] Aschenanalysen, 1880.

Minor Mineral Constituents. *Iron.*—Oat meal 37 mg. per kilo (Sherman).[1] Spring oats, 8 samples, 34 to 78, aver. 50 mg. per kilo, dry basis (McHargue).[2]

Aluminum.—Oats 5.2 mg. per kilo, dry basis (Bertrand and Lévy).[3]

Manganese.—Oats 23 mg. per kilo, dry basis (Wester).[4] Spring oats, 8 samples above noted, 35 to 60, aver. 49 mg. per kilo, dry basis (McHargue).[2] Oats 8.8 mg. per kilo, air dry basis (Quartaroli).[5] Oats, 5 varieties, 66 to 204 mg. per kilo, dry basis (Davidson).[6]

Copper.—Oats 17.1 mg. per kilo, air dry basis (Guerithault);[7] 3.81 mg. per kilo, air dry basis (Quartaroli).[5]

Zinc.—Oats 32 to 49 mg. per kilo, air dry basis (Birckner).[8] Oats 22 mg. per kilo, dry basis (Bertrand and Benzon)[9].

Arsenic.—Oat kernel 0.5 mg. per kilo (Jadin and Astruc).[10]

WILD OATS

Avena fatua L.

Fr. Folle avoine. Sp. Avena silvestre. It. Avena sterile. Ger. Flughafer.

Whether or not this form of oats is the progenitor of the cultivated varieties, it is at least a closely related species, with gross and minute structure much the same.

MACROSCOPIC STRUCTURE.—As grown in American grain fields and separated in the screenings, the *grain* is commonly dark gray-brown with a prominent strongly twisted *awn* (Fig. 80). Some cultivated varieties also yield dark-colored oats, but these have other characters corresponding with the light-colored varieties, whereas wild oats differ in having conspicuous *hairs* on the *rachilla* and at the base of the *flowering glume* and *awn* of both fruits.

MICROSCOPIC STRUCTURE.—As seen under the microscope, the hairs of the chaff (Fig. 81) reach over 5 mm. in length and 40 μ in breadth in the central portion but only about half that breadth at the base. The lumen, which does not differ greatly from the walls in thickness, con-

[1] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.
[2] J. Agr. Res. 1923, **23**, 395.
[3] Compt. rend. 1931, **192**, 525.
[4] Biochem. Z. 1921, **118**, 158.
[5] Ann. chim. appl. 1928, **18**, 47.
[6] Cereal Chem. 1929, **6**, 128.
[7] Compt. rend. 1920, **171**, 196.
[8] J. Biol. Chem. 1919, **33**, 191.
[9] Bul. soc. hyg. aliment. 1928, **16**, 457.
[10] Compt. rend. 1912, **155**, 291.

tains either a dark brown or a colorless substance. In addition to long forms, very short hairs, 100 μ or less in breadth, also occur.

Fig. 80.

Fig. 81.

Fig. 80.—Wild Oats. Two-fruited spikelet. (See Fig. 70, I.) ×2. (A.L.W.)
Fig. 81.—Wild Oats. Apex, middle, and base of hair 3.2 mm. long from rachilla. ×160. (A.L.W.)

Chief Structural Characters.—Grain dark colored; rachilla and base of flowering glume and awn bristly. Otherwise like cultivated oats.

MANNA GRASS

Glyceria fluitans R. Br. = *Panicularia fluitans* (L.) Kuntze.

Fr. Herbe à la manne. Ger. Mannagras.

This species grows wild in swamps of Europe and America. According to T. F. Hanausek [1] the grain is sold in the market places of Danzig, Elbing, and Königsberg and is used for making soups. Although of relatively small importance as food, its study gives a better insight into the tribe *Festuceæ* to which belong *Poa, Festuca,* and other genera of agricultural grasses. The specimen examined was from Simferpol, Crimea, furnished by Mr. H. S. Skeels, Office of Seed and Plant Introduction, Bureau of Plant Industry.

MACROSCOPIC STRUCTURE.—The *spikelets* are borne in long one-sided panicles. The number of *flowers* in the spikelet varies up to twelve. At maturity, the *fruit,* which readily separates from the enveloping flowering glume and palet, resembles a grain of wheat in shape

[1] Nahr.-Genuss. aus dem Pflanzenreiche. Kassel, 1884, p. 56.

but is only 2 to 2.5 mm. long, beardless, brown, and lustrous; furthermore, the groove is relatively broad and shallow. The *flowering glume* is 4 to 5 mm. long, blunt, with seven prominent ribs; the *palet* is thin and without nerves. Both bear short stiff *hairs*, visible under a lens, which make the surface rough to the touch. Somewhat longer hairs occur on the nerves.

MICROSCOPIC STRUCTURE.—Harz [1] has made a comparative study of the fruits of *G. fluitans*, *G. spectabilis*, and *Festuca elatior* in cross section but not in surface view.

Flowering Glume and Palet.—These are remarkable for their stiff *hairs*. Although thick-walled these are so broad at the base (often 15 μ) that the lumen is broader than the walls. The hair scars or round cells are correspondingly broad. Sometimes they are accompanied by crescent cells. The elongated cells alternating with the hairs are often indistinct in outline.

Pericarp.—In cross section, details of structure are not clear until after special treatment as with sodium hydroxide or Javelle water and staining with chlorzinc iodine or safranin.

In surface view, three layers are evident: (1) *epicarp* of transversely much elongated narrow cells, often side by side in rows, (2) vermiform *cross cells* occurring here and there, and (3) numerous *tube cells*.

The *epicarp* cells because of their transverse elongation are remarkable.

Spermoderm.—Equally remarkable are the cells of this coat, which reach 10 μ in thickness as seen in cross section. The radial walls are thin, the tangential walls thick and become still thicker on treatment with sodium hydroxide. A cuticle is present on both the outer and inner surface of this layer, staining yellow with chlorzinc iodine, whereas the walls proper stain blue. In surface view, the cells are more or less rectangular, nearly isodiameteric and arranged often in rows.

Perisperm.—This layer is seldom evident in cross section, even after treatment with the reagents and stains named above. In surface view, the cells may often be seen. They are narrow, more or less elongated, and usually diagonally arranged. The walls are indistinctly beaded.

Endosperm.—The *aleurone cells* and *starch cells* with compound grains of the rice type are not characteristic.

CHIEF STRUCTURAL CHARACTERS.—Grain naked, resembling wheat but smaller, beardless, and with broad but shallow groove.

Epicarp cells transversely elongated, side by side in rows. Spermoderm thick with isodiametric cells. Starch of rice type.

[1] Samenkunde. Berlin, 1885, p. 1302.

CHEMICAL COMPOSITION.—An analysis by Hartwich and Håkanson[1] gave:

Water	Protein	Fat	Starch and sugar	Fiber	Ash
%	%	%	%	%	%
13.54	9.69	0.43	75.06	0.21	0.61

CORACAN

Eleusine coracana Gaertn. = *Cynosurus coracanus* L.

Ger. Fingerhirse.

This cereal, also known as African millet, like the sorghums and pearl millet (*Pennisetum typhoideum* Rich.) is extensively grown by the natives in central and southern Africa and to some extent in Egypt and Abyssinia. Its cultivation is by no means limited to Africa, in fact De Candolle emphasizes its occurrence in India and the Malay Archipelago and concludes that India is its country of origin. Narayana and Norris [2] state that under the name of "ragi" it is the staple crop of the state of Mysore, India, where it forms the chief diet of the lower classes.

De Candolle's statement that its cultivation is not widespread in Africa is at variance with the reports of other scientists. Warburg [3] did not find it in southern Angola but refers to its importance in central Africa and mentions its Kaffir name "luku." Mitlacher [4] states that coracan ranks with sorghum as a staple cereal in central Africa and that it is grown in German East Africa under the name "uimbi." He also refers to its cultivation in Japan and southern China as well as in India and the Sunda Islands. V. Dalla Torre [5] agrees with Mitlacher as to its distribution and considers it the chief food of the African natives. He believes it to be a form of *E. indica*. Reverend Fred R. Bunker, who spent thirty years in Rhodesia and neighboring provinces, has stated to the writers that it has long been a common bread cereal of the Amandau people of Mozambique, being known as "upoko" or "umngoza," furthermore that it yields bread of excellent flavor notwithstanding the statements that it has a bitter taste.

[1] Z. Unters. Nahr.-Genussm. 1905, **10**, 143.
[2] J. Ind. Inst. Sci. 1928, **11A**, pt. 8, 91.
[3] Kunene-Sambesi Expedition, p. 488.
[4] Z. allg. oesterr. Apoth.-Ver. 1901, 813, 831, 856, 875, 899, 928.
[5] Real.-Enz. ges. Pharm. Berlin, 2 Aufl. 1905, **4**, 634.

MACROSCOPIC STRUCTURE.—Unlike all other common cereals the fruit is a utricle with a thin, papery *pericarp* which is not grown to the seed. The *seed* is irregularly globular or oval, 1 to 1.5 mm. in diameter, of a rich red-brown color. As seen under a lens the surface is roughened by numerous warts arranged in irregular longitudinal rows, and the location of the embryo is marked by a flattened or depressed area extending from the base to beyond the middle of the seed.

MICROSCOPIC STRUCTURE.—Most authors either ignore this cereal or merely give it passing mention. Mitlacher,[1] however, describes its structure in detail.

Pericarp.—Mitlacher observes that the tissues are collapsed and show little structure except at the base, where he found remains of the *epicarp*

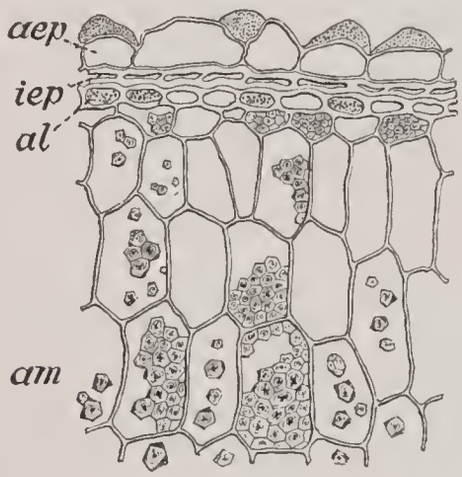


FIG. 82.

FIG. 83.

FIG. 82.—Coracan. Seed in cross section. Spermoderm: *aep* outer epiderm with warts, *iep* inner epiderm. Endosperm: *al* aleurone cells, *am* starch parenchyma. ×160. (A.L.W.)

FIG. 83.—Coracan. Spermoderm in surface view showing outer epiderm. ×160. (A.L.W.)

with thin walls and of the *hypoderm* (middle layer) with thick but indistinct walls.

In our specimen we have found only one distinct layer at the base and this has thick, beaded walls. The cells are polygonal and more or less longitudinally elongated. Whether the layer is epicarp or hypoderm is uncertain.

Spermoderm (Figs. 82 and 83).—Whereas in all other common cereals the spermoderm is often so delicate as to escape notice except after long search, in coracan it is strongly developed.

The *outer epiderm* (*aep*) consists of wavy-walled isodiametric red-brown cells, each with a wart in the middle, arranged for the most part

[1] Loc. cit.

in irregular longitudinal rows. In suitable mounts the cuticle shows a finely granular surface.

Mitlacher states that these cells in surface view are elongated and each has two or three warts in a row. His illustration further shows this conception of the structure. It is true that the appearance of an untreated surface preparation often is consistent with his interpretation, but on heating with sodium hydroxide it may be demonstrated that the cells are isodiametric, each with a single wart. The walls parallel to the axis of the seed are more or less distinctly wavy and clearly evident without special treatment, but the walls at right angles to these are nearly straight and not always evident in untreated mounts.

The *inner epiderm* (*iep*), as in wheat, is darker than the outer epiderm. As may be seen in cross section, the outer and inner walls, especially after treatment with sodium hydroxide, are swollen, whereas the radial walls are thinner. In surface view, this layer is not commonly seen, as it is closely adherent to the outer epiderm. Mitlacher states that after long soaking in sodium hydroxide the two layers may be separated. Thus obtained, the cells of the inner epiderm are seen to have wavy walls which appear to form two layers owing to the tipping over of the radial walls.

Endosperm (Fig. 82).—The *aleurone cells* (*al*) are small and form a thin layer. They resemble the aleurone cells of broom corn. The *starch cells* (*am*) contain *starch grains* like those of maize and sorghum but of smaller size, seldom if ever exceeding 20 μ in diameter. Polygonal grains occur in the outer horny portion, round grains in the floury central portion. Aggregates of from two to many grains occur in limited numbers.

Embryo.—This is relatively large. The radicle, according to Mitlacher, extends from the rather long hypocotyl outward at nearly right angles to the axis of the plumule.

Chief Structural Characters.—Pericarp papery. Seed loose, brown.

Spermoderm with warty, wavy-walled outer epiderm. Starch grains of maize type but smaller.

CHEMICAL COMPOSITION.—Church [1] in his study of Indian foods analyzed whole and husked coracan; Adolph [2] gives an analysis made in China where the grain is known as *Ts'au-tzu;* and Narayana and Norris [3] give the average composition of the whole grain from India.

[1] Watt's Dict Econ. Prod. India, Calcutta, 1889.

[2] Philippine J. Sci. 1926, **30**, 287.

[3] Loc. cit.

Composition of Coracan

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Church:						
Whole grain	12.5	5.9	0.8	74.6	3.6	2.6
Husked grain	13.2	7.3	1.5	73.2	2.5	2.3
Adolph	8.50	5.84	5.75	74.26	2.01	3.64
Narayana and Norris	0.00	8.4	1.7	83.8	3.4	2.7

Balland [1] gives the composition of the grain of *E. stricta* as: water 13.50, protein 6.76, fat 1.15, nitrogen-free extract 70.94, fiber 4.35, and ash 3.30 per cent.

Proteins.—Narayana and Norris [2] found that the protein matter of the grain consisted largely of a prolamine to which they gave the name *eleusinin*. It was soluble in 70 per cent alcohol and was separated by evaporation under reduced pressure until a precipitate appeared, when the liquid was filtered and the filtrate poured with stirring into ten volumes of distilled water. Sodium chloride precipitated eleusinin in the form of plates. It was purified by repeated solution and reprecipitation and finally extracted with ether to remove the fat.

The *Ultimate Composition* was found to be:

	%
Carbon	53.29
Hydrogen	7.35
Nitrogen	15.91
Oxygen	23.34
	99.89

Nitrogen Distribution.—Plimmer's modification of Van Slyke's method yielded the following amounts of nitrogen in the different forms, expressed in percentages of the total nitrogen: amino N 69.03, non-amino N 2.13 (total non-basic N 71.16); arginine N 2.60, lysine N 0.64, histidine N 2.69 (total basic N 5.93); amide N 20.52, insoluble humin N 0.87, soluble humin N 0.28; total 98.76. Tyrosine N and tryptophane N were present, but cystine N probably was not.

Enzymes.—*Amylase* of coracan, as examined by Patwardhan and

[1] Compt. rend. 1902, **135**, 1079.
[2] Loc. cit.

Narayana,[1] had greater diastatic power than that of maize malt but less than that of barley malt.

DARNEL

Lolium temulentum L.

Fr. Ivraie. Sp. Cizana. It. Doglio. Ger. Taumellolch.

European investigators consider this weed seed highly objectionable in grain because of the presence of temulin, a poisonous principle. It occurs not only in European grain fields but also in the American Northwest and California. Darnel is thought to be the " tares " of Scripture.

MACROSCOPIC STRUCTURE.—The spikelet is four- to eight-flowered. The single *empty glume*, at the base of the spikelet away from the rachis, remains with the straw on threshing. The *flowering glume* of each flower is 6 to 8 mm. long, equaling or exceeding the *fruit* (caryopsis), obscurely five-nerved and lobed at the end. It bears an *awn* up to 15 mm. or more in length. The *palet* is of thinner texture, two-keeled, and winged. A *groove* occurs on the ventral side as in wheat but is relatively broader and deeper. Both flowering glume and palet closely invest the fruit.

MICROSCOPIC STRUCTURE.—Winton [2] finds two layers of cells each in the spermoderm and perisperm, thus disagreeing with Vogl,[3] who finds two and one, and Villiers and Collin,[4] who find one and two, respectively. The curious fungous layer has been studied by Vogl,[5] Hanausek[6] and Nestler.[7]

Flowering Glume.—Over the body of the grain four coats are present as in other chaffy cereals: (1) *outer epiderm* (Fig. 84) made up of wavy-walled cells both short and long, round cells, twin cells (one of which may be a round cell), and rows of stomata, (2) *hypoderm fibers*, (3) *spongy parenchyma* with more or less quadrilateral cells, and (4) *inner epiderm* of thin-walled cells and stomata.

The *outer epiderm* is remarkable for the great number, large size, and pitted walls of the round cells, which in parts occupy the greater part

[1] J. Indian Inst. Sci. 1930, **13A**, 38.

[2] Connecticut Agr. Exp. Sta. Rep. 1903, 165; Z. Unters. Nahr.-Genussm. 1904, **7**, 321.

[3] Wicht. Nahr.-Genussm. Berlin, 1889, p. 32.

[4] Traité des altérations et falsifications des substances alimentaires. Paris, 1900, p. 92. In 2nd Ed. (1909) cut and text are revised to show two layers in each.

[5] Loc. cit.

[6] Ber. deut. bot. Ges. 1898, **16**, 203.

[7] Ibid. 207.

of the area, reducing the length of the wavy-walled cells or crowding them out entirely. Although the walls of the wavy-walled cells are thick, they are indistinct, whereas the middle lamella is conspicuous, giving the appearance of thin-walled cells. On the thin borders the wavy-walled cells become straight-walled, and the only other elements are short, often hooked, *hairs* with broad base (Fig. 85).

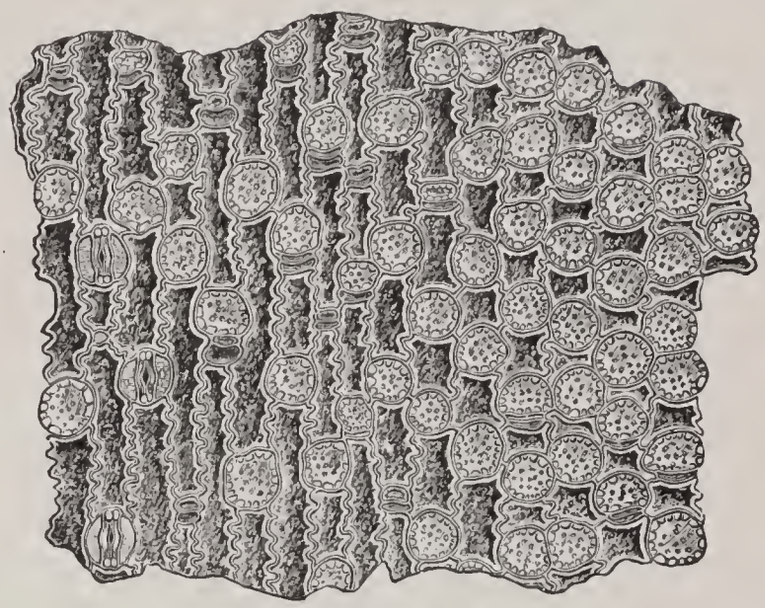


Fig. 84.—Darnel. Middle portion of flowering glume in surface view showing outer epiderm. ×160. (A.L.W.)

Hypoderm fibers occur not only as the second coat of the flowering glume but also as the chief tissue of the awn.

Palet.—Although of the same general structure as the flowering glume, the palet is thinner and more membranous, owing to the absence of a continuous well-developed hypoderm coat.

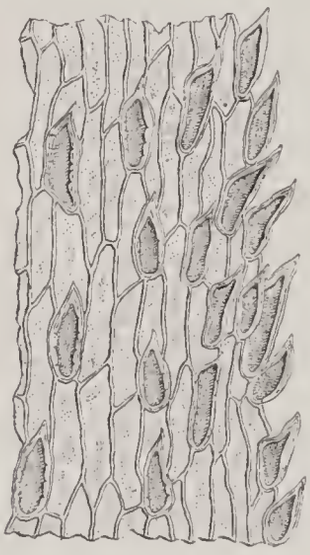


Fig. 85.

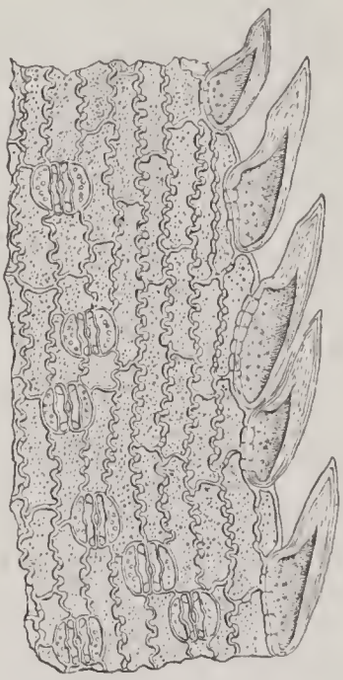


Fig. 86.

Fig. 85.—Darnel. Thin margin of flowering glume in surface view showing outer epiderm with hairs. ×160. (A.L.W.)

Fig. 86.—Darnel. Keel of palet in surface view showing outer epiderm with hairs and stomata. ×160. (A.L.W.)

The *outer epiderm*, though for the most part like that of the flowering glume, is characterized by the presence of thorn-like *hairs* on the keels

(Fig. 86). The presence of stomata and the absence of round cells in this region are noteworthy.

Pericarp (Fig. 87, *F*; Fig. 88).—Four layers are normally present: (1) *epicarp* (*ep*) of indistinctly beaded cells, elongated except at the apex, where they are isodiametric, (2) *hypoderm* (*m*) made up of various shaped cells, (3) *cross cells* (*q*), and (4) *tube cells* or endocarp (*sch*).

The *hypoderm* is well developed at the angles but absent in parts. The *tube cells* form an interrupted layer and in parts run into spongy parenchyma. Especially striking are the *cross cells*, which suggest the corresponding cells of barley although in only one layer.

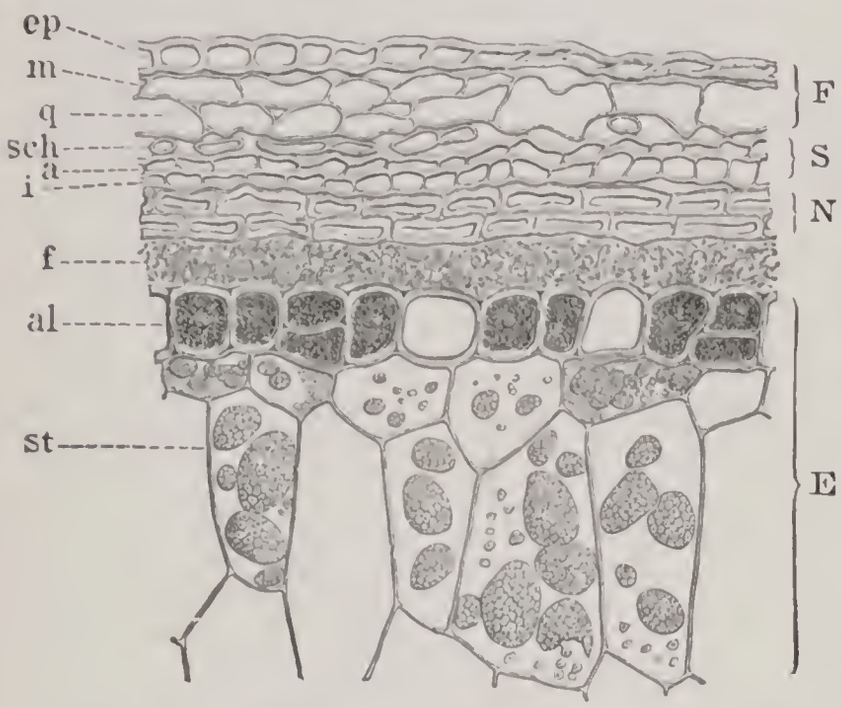


FIG. 87.—Darnel. Kernel in cross section. *F* pericarp: *ep* epicarp, *m* mesocarp, *q* cross cells, *sch* tube cells. *S* spermoderm: *a* outer layer, *i* inner layer. *N* perisperm. *f* fungous layer. *E* endosperm: *al* aleurone cells, *st* starch cells. ×160. (A.L.W.)

Spermoderm (Fig. 87, *S*; Fig. 88).—Surface preparations show the two layers of elongated, often diagonally arranged, cells with thin walls, suggesting the two spermoderm layers found in wheat and rye. Examined in water, only the inner of the two layers is usually seen, but by heating with sodium hydroxide, acidifying with acetic acid, and treatment with chlorzinc iodine the other layer is brought out.

In cross section the spermoderm often separates from both the pericarp and the perisperm. The *outer layer* (*a*) is characterized by an outer cuticle staining yellow and the inner and radial walls staining blue; the *inner layer* (*i*) is characterized by an inner cuticle staining yellow and the thicker walls swelling further by the treatment and staining blue.

Perisperm (Figs. 87 and 88, *N*).—Treatment as above described aids in bringing out the two layers in cross section, the cells being rectangular and stained blue. After long soaking in sodium hydroxide the irregularly polygonal, more or less elongated, form is evident in surface view.

Fungous Layer (Figs. 87 and 88, *f*).—In most specimens a layer of fungous hyphæ, about 20 μ thick, occurs between the perisperm and aleurone layer. Treated as above described, the hyphæ stain yellow. Although not an organic part of the seed, the fungous layer is so gen-

erally present as to be characteristic and no little aid in the examination for darnel as an impurity of mill products.

Endosperm (Fig. 87, *E*; Fig. 88).—*Aleurone cells* (*al*) 20 to 40 μ, and *starch cells* (*st*) with small polygonal grains up to 7 μ in diameter, occurring in aggregates, characterize the endosperm. The *starch grains* are not distinguishable from those of oats and rice.

Chief Structural Characters.—Grain chaffy; kernel longer than wheat with broader and deeper groove.

Chaff with numerous round cells and thorn-like hairs. Epicarp without hairs; cross cells thin-walled, as in barley, but forming only one

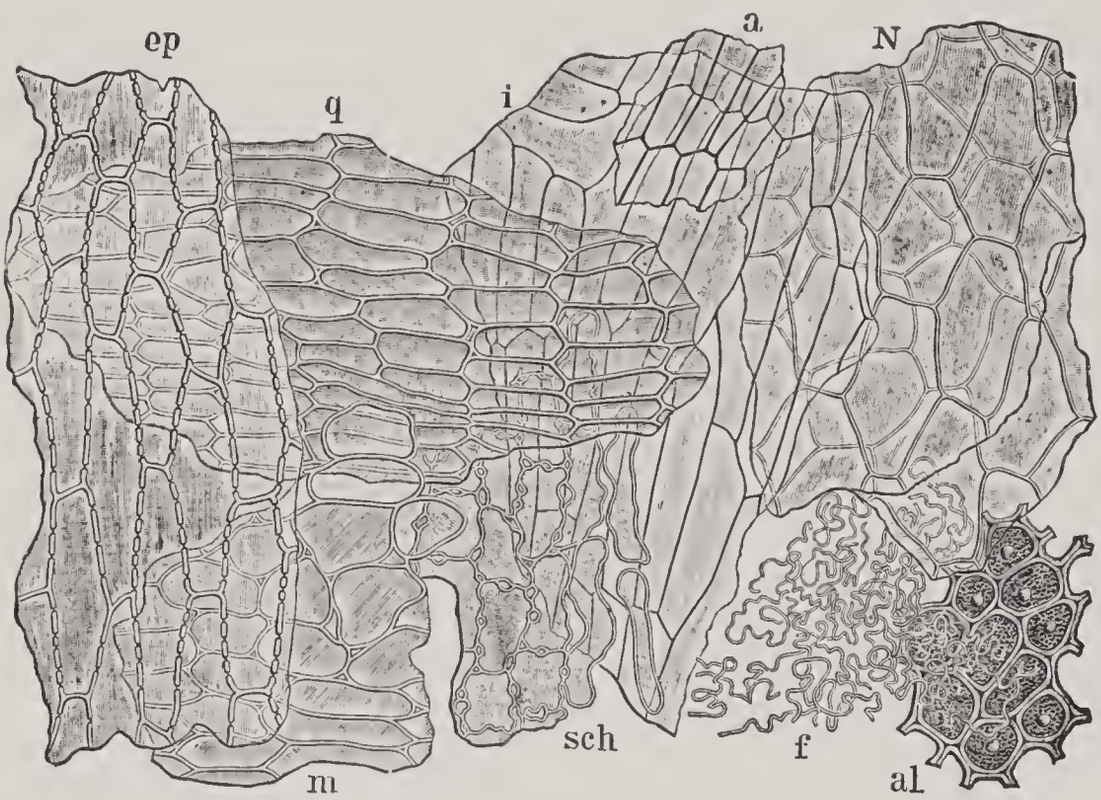


Fig. 88.—Darnel. Bran coats in surface view. *ep* epicarp; *m* mesocarp; *q* cross cells; *sch* tube cells; *a* outer layer and *i* inner layer of spermoderm; *N* perisperm; *f* fungous layer; *al* aleurone cells. ×160. (A.L.W.)

cell layer; modified tube cells forming spongy parenchyma. Fungous layer characteristic. Starch of rice type.

CHEMICAL COMPOSITION.—No record of a proximate analysis has come to light, but the composition may be assumed to come within the range of that of oats.

According to Hofmeister,[1] darnel contains a poisonous substance, *temulin*, classed as a narcotic alkaloid. The hydrochloride is stated to have the formula $C_7H_{12}N_2O_2HCl$. It is supposed to owe its origin to the fungus which occupies the space between the endosperm and the perisperm and which may act on the protein matter of the aleurone layer.

[1] Abs. Chem. Centralbl. 1892, II, 657.

If this theory is correct, other forage species of *Lolium*, which according to Neubauer [1] have a fungous layer, must also be poisonous.

Mineral Constituents.—An early analysis of the ash by Ramdohr [2] given below, although quantitatively as shown by the footing (104.52) somewhat lacking in accuracy, is qualitatively correct and is worthy of notice because it shows that recent work on the rarer elements is but a revival.

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	Mn_2O_3	CuO	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%	%	%
22.42	3.48	6.11	9.40	1.57	0.20	3.59	0.53	19.64	0.25	30.09	0.15

CHESS

Bromus secalinus L.

Fr. Brome des seigles. Sp. Bromo. It. Bromo. Ger. Trespe.

In both Europe and America, chess, or cheat, is a troublesome weed, especially in wheat fields. In the United States it is a serious pest chiefly in the soft wheat section of the Middle West, where Hitchcock and Norton (Kansas), Selby (Ohio), Beal (Michigan), and others note its frequent occurrence, while Bolley and Waldron (North Dakota) and Oswald (Minnesota), located in the Northwestern spring wheat section, do not mention it in their weed bulletins.

It is a popular belief that wheat degenerates into chess.

MACROSCOPIC STRUCTURE (Fig. 89).—The several-flowered spikelet is subtended by two *empty glumes* but these remain with the straw on threshing. The five-nerved *flowering glume* tightly clasps the two-keeled, two-winged *palet*, and the *fruit*, the whole resembling darnel except that the latter is longer awned. It may or may not bear an *awn* attached a little below the tip and varying in length up to about that of the chaff-invested fruit. Bristle-hairs occur along the edges. The palet lies close to the fruit, which is deeply grooved, and reaches 6 mm. in length. The *embryo* is short (1 mm.)

MICROSCOPIC STRUCTURE.—Vogl [3] and also Winton [4] have published results of histological studies of chaff and fruit.

[1] Centralbl. Bakt. 1902, **9**, 652.

[2] Chem. Centralb. 1856, p. 349.

[3] Wicht. Nahr.-Genussm. Berlin, 1899, p. 36.

[4] Connecticut Agr. Exp. Sta. Rep. 1903, p. 165; Z. Unters. Nahr.-Genussm. 1904. **7**, 321.

Flowering Glume.—As in barley four coats are present: (1) *outer epiderm* with narrow, wavy-walled long cells, and round cells, also twin cells (Fig. 90), (2) *hypoderm* made up of thick-walled fibers, (3) *spongy parenchyma* with quadrilateral cells, and (4) *inner epiderm* of cells with straight, thin walls and stomata.

The round cells of the epiderm, unlike those of darnel, have wavy walls. At the margins the tissue consists of elongated cells with thin, straight walls and numerous thorn-like or lance-shaped *hairs*, whereas in barley such hairs occur sparingly and only toward the tip.

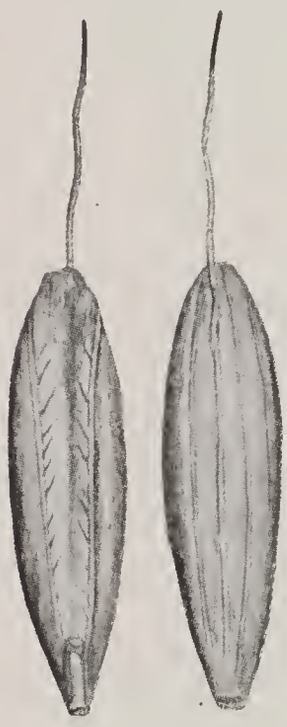


Fig. 89.

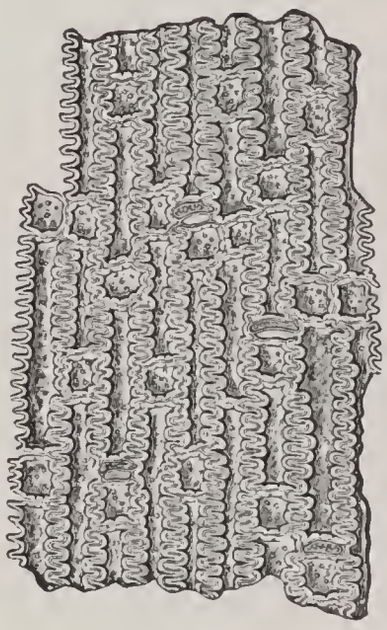


Fig. 90.

Fig. 89.—Chess. Kernel with chaff. Left, ventral side showing palet, covering groove of kernel, with rows of hairs on keels and joint of rachilla at base. Right, dorsal side showing veins of flowering glume and awn attached below tip. ×5. (A.L.W.)

Fig. 90.—Chess. Flowering glume in surface view showing outer epiderm. ×160. (A.L.W.)

Palet.—The structure is much the same as that of the flowering glume but the keels are barbed with stiff *hairs* up to 45 μ long.

Pericarp (Fig. 91, *F*; Fig. 92).—Only two well-defined layers are present: (1) *epicarp* (*ep*) with longitudinally elongated polygonal cells with non-porous walls, and (2) *spongy parenchyma* (*q*), the cells of which are both transversely and longitudinally elongated and probably correspond both to the cross cells and the tube cells of other cereals. Traces of a *hypoderm* may be found in cross section.

Spermoderm (Figs. 91 and 92, *S*).—One layer of elongated thin-walled cells of brown color is present.

Perisperm (Figs. 91 and 92, *N*).—Compared with the common cereals, this layer shows remarkably robust development. In cross section the

FIG. 91.—Chess. Kernel in cross section. *F* pericarp: *ep* epicarp, *q* cross cells. *S* spermoderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *st* starch cells. ×160. (A.L.W.)

layer is 40 μ thick and both outer and inner walls are so swollen as to nearly obliterate the cavity. In surface preparations, obtained by soak-

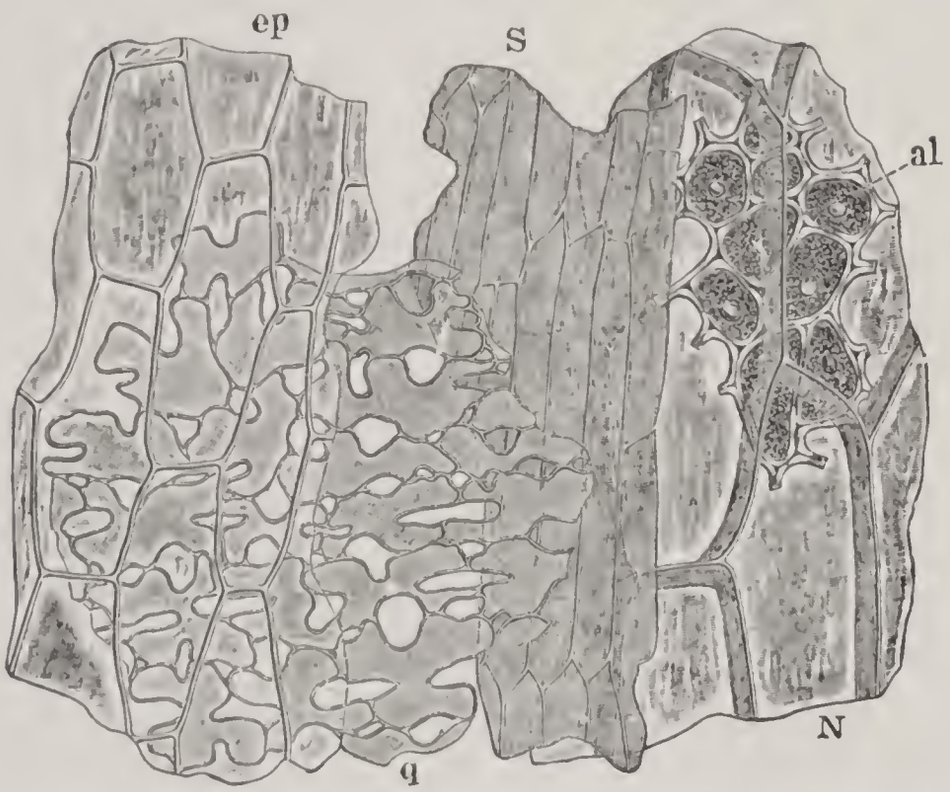


FIG. 92.—Chess. Bran coats in surface view. *ep* epicarp; *q* cross cells; *S* spermoderm; *N* perisperm; *al* aleurone cells. ×160. (A.L.W.)

ing in sodium hydroxide, the cells are conspicuous for their size and often for the tipped-over radial walls, which give them a shaded appearance.

Endosperm (Fig. 91, *E*; Fig. 92).—The *aleurone cells* (*al*) are not characteristic; on the other hnad, the starch cells (*st*) are remarkable because of the thick walls (10 μ or more) and the more or less elliptical *starch grains* up to 20 μ with elliptical hilum.

Chief Structural Characters.—Fruit (6 mm.) grooved, with oat-like chaff, awned or awnless.

Palet with thorn-like hairs on keels (distinction from barley). Flowering glume and palet with rectangular spongy parenchyma cells (distinction from oats), also long cells and round cells with wavy walls (distinction from darnel). Perisperm swollen, conspicuous in cross section. Endosperm with swollen walls; starch grains elliptical (20 μ), unique.

TEFF

Eragrostis abyssinica Link = *Poa abyssinica* Jacq.

Fr. Teff. Ger. Tef.

Hackel considers this cereal as having been derived from *E. pilosa* Beauv. by cultivation. It is a valuable bread grain in Abyssinia.

MACROSCOPIC STRUCTURE.—The ovate *fruit* ranges from white to red in color and reaches 1 mm. or slightly more in length; the *embryo* is half or more the length of the fruit. Although clothed when mature in the papery *flowering glume* and *palet*, the commercial grain is naked except for an occasional kernel.

MICROSCOPIC STRUCTURE.—Mitlacher [1] has studied the chaff and caryopsis. Our observations on white and red teff, obtained from Abyssinia by the Office of Seed and Plant Introduction, U. S. Department of Agriculture, confirm his results.

Flowering Glume and Palet.—The *outer epiderm* consists of wavy-walled long cells, twin cells, and short thorn-like *hairs* or hair scars (round cells).

Pericarp.—Only the *epicarp* with longitudinally elongated, slightly wavy-walled cells is evident.

Spermoderm.—A second layer also of elongated cells but with thicker and more wavy walls Mitlacher considers as spermoderm. It is this coat or its cuticle that is colored in the red variety.

Endosperm.—The *aleurone cells* and *starch cells* with grains of the rice type are characterless. In starch cells adjoining the endosperm Mitlacher finds small prismatic and rosette crystals, also combinations of one of each, like those in the leaf of *Hyoscyamus niger* but smaller.

[1] Z. allg. oesterr. Apoth.-Ver. 1901, 813, 831, 856, 875, 899, 928.

CHIEF STRUCTURAL CHARACTERS.—Kernel very small (1 mm.), readily separating from papery chaff.

Flowering glume and palet with epiderm of wavy-walled long cells, twin cells, and short hairs or hair scars. Epicarp of elongated, slightly wavy-walled cells; other pericarp tissues lacking. Spermoderm of elongated cells with distinctly wavy walls. Starch of rice type.

CHEMICAL COMPOSITION.—Balland [1] gives the following analysis:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
9.20	8.36	1.85	75.49	1.90	3.20

COMMON WHEAT

Triticum sativum Lam. = *T. vulgare* Vill. = *T. hibernum* + *T. æstivum* L.

Fr. Blé. Sp. Trigo. It. Frumento. Ger. Weizen.

De Candolle considers common wheat as the most ancient of the present cultivated forms of *Triticum*, its original habitat being Western Asia, and that several kinds formerly given specific names are probably varieties derived from common wheat through the centuries. This is in accord with Hackel's classification which makes macaroni, Polish, and English wheat, also spelt and emmer, varieties of *T. sativum* Lam., the specific names formerly used being retained as varietal names. In view of the position of common wheat as the parent, the varietal name *vulgare*, used by Hackel, seems superfluous.

Throughout the temperate zones of Europe, North and South America, and Australia, wheat is the chief bread cereal except in restricted localities where it shares this honor with rye, maize, oats, or even barley. Wheat grown in the colder countries is planted in the Spring, whereas in the warmer sections it is planted in the Fall but makes its chief growth the next season. This has given rise to so-called Winter and Spring varieties and the two Linnean species into which they were formerly grouped.

MACROSCOPIC STRUCTURE.—The wheat kernel varies from light buff or yellow to red-brown, without the dirty or greenish cast characteristic of rye, and from blunt spindle-shaped to ovate. It is not

[1] Compt. rend. 1902, **135**, 1079.

sharp pointed as is rye although the apex is commonly narrower than the base. In some varieties the ratio of breadth to length is 4 : 6, in others it reaches 3 : 9. These figures also represent approximately the dimensions in millimeters of the largest grains. The kernel may be quite evenly rounded or somewhat triangular in cross section. The *groove*

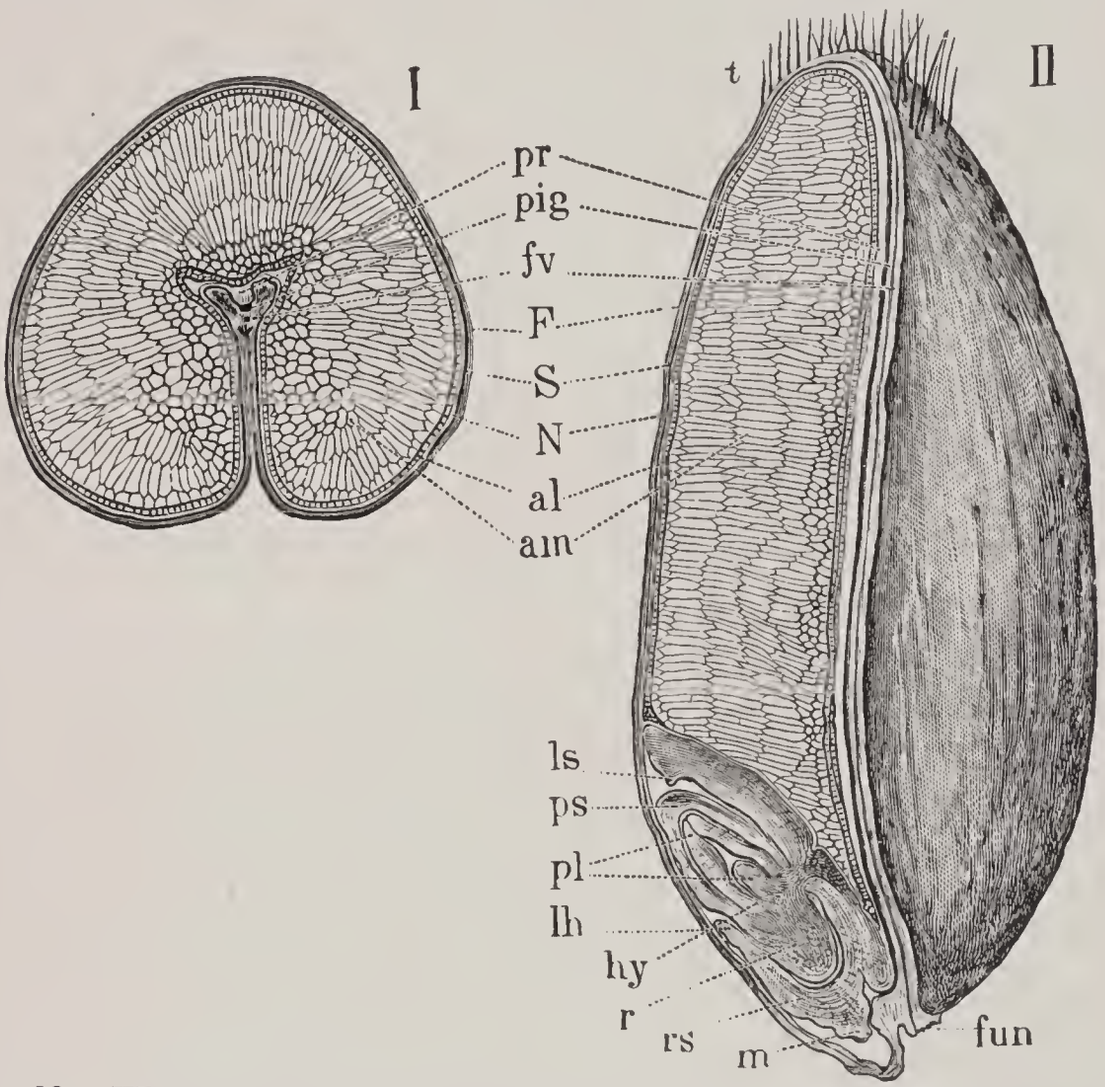


FIG. 93.—Wheat. Kernel in transverse (I) and longitudinal (II) section. *F* pericarp: *t* hairs at apex. *S* spermoderm enlarged along the groove into *pig* pigment strand adjoining *fv* bundle of the raphe. *N* perisperm enlarged along the groove into *pr* perisperm strand. Endosperm: *al* aleurone layer, *am* starch cells. Embryo: scutellum, adjoining endosperm, with *ls* ligule, *pl* plumule, *ps* plumule sheath, *hy* hypocotyl with *lh* ligule, *r* radicle, *rs* coleorhiza or radicle sheath. *m* micropyle. *fun* funiculus. × 15 (A.L.W.)

on the ventral side extends the entire length. The apex is clothed with a tuft of *hairs* evident to a sharp eye or with a lens.

The *embryo* or *germ* is on the dorsal side extending from the base to about one-third of the length of the kernel, its position being evident by a shriveling of the surface.

In median longitudinal section (Fig. 93, II) cut through the groove after soaking for some hours in water, the general structure of the embryo and the tissues along the groove are evident under a lens or

with low magnification under the microscope. The figure shows the *embryo*, consisting of (1) *hypocotyl* or embryonic stem (*hy*) with the *ligule* (*lh*), (2) the *plumule* or leaf bud (*pl*), encased in the *plumule sheath* (*ps*), (3) the primary *radicle* or embryonic root (*r*) encased in the *coleorhiza* or radicle sheath (*rs*), the *radicle cap* being immediately adjoining the radicle tip, and (4) the *scutellum*, which adjoins the starchy endosperm (*am*), with its ligule (*ls*). This cut in addition shows the *micropyle* (*m*) or opening of the spermoderm through which the pollen tube entered in fertilization, the *funiculus* or fruit stem (*fun*), the tuft of *hairs* (*t*) at the tip, also the *pericarp* (*F*), the *spermoderm* (*S*) enlarged along the bottom of the groove and becoming the *pigment strand* (*pig*) with the *fibro-vascular bundle* (*fv*) adjoining, the *perisperm* (*N*) enlarged along the bottom of the groove as the *perisperm strand* (*pr*), and the *aleurone* or *gluten layer* (*al*) of the endosperm. The cut does not show the secondary radicles. These are best studied in cross sections through the basal end of the kernel. Two of these may usually be found in wheat although, according to Harz,[1] the number may reach four. In the variety represented in Fig. 93, two were present, but being one either side of the main radicle they do not appear in a median section.

In cross section (Fig. 93, I) the kernel is irregularly heart-shaped. The groove is seen to extend to about the center, being closed for most of the distance. At the center this section shows clearly the broadening of the bran tissues, the *pericarp* and *spermoderm* forming a Y, in the top angle of which the spermoderm is expanded into the *pigment strand* (*pig*) while the *perisperm strand* (*pr*), an enlargement of the colorless perisperm, fills the remainder of the angle, the whole being bordered by the *endosperm* forming an irregular triangle.

The proportion of horny to floury endosperm varies according to the hardness of the variety.

MICROSCOPIC STRUCTURE.—All the treatises on the microscopy of foods, especially cereals, as well as most of the works on pharmacognosy and food analysis, describe the histology of wheat, although too often undue emphasis is laid on the elements of diagnostic value, to the neglect of structural details of scientific and technical importance, notably of the embryo and the tissues about the groove.

Longitudinal sections show certain details of the bran coats and embryo, whereas cross sections give a better idea of the bran coats, especially in the groove. The kernel may be cut with a Gillette blade moist, after soaking for some hours in water, or dry. Surface preparations obtained by scraping show best the diagnostic characters of the bran coats.

[1] Samenkunde, p. 1179.

Pericarp (Figs. 94 and 95).—Five thin, dry layers of no evident food value form the outer bran tissues: (1) *epicarp* (*epi*) consisting of porous (consequently beaded), rather thick-walled cells, which on the body of the grain are longitudinally elongated and alternately arranged, while at the apex they are isodiametric-polygonal and interspersed with *hairs* (*t*); (2) *hypoderm* (*hy*) of a distinct layer of cells similar to those of the epicarp, except for the absence of hairs, and one or more layers with thinner walls more or less collapsed; (3) scattered groups of *intermediate cells* (*in*) of curious form, having walls partly with and partly without pores, often with intercellular spaces; (4) *cross cells* (*tr*), distinctly pitted (beaded), rather thick-walled cells transversely elongated and for the most part arranged side by side in rows; and (5) *endocarp* consisting of *tube cells* (*tu*), isolated or in loose contact, often with round intercellular spaces.

The *hairs* of the epicarp vary up to 1 mm. long and, as noted by Wittmack,[1] usually have a lumen narrower than the wall thickness, whereas the reverse is true of rye hairs. They are broad or globular at the base and taper to a rather sharp point. As shown in Fig. 79, oat hairs are longer and much narrowed at the base.

The *epicarp*, *hypoderm*, and *cross cells*, as seen in surface view, have very distinct pores even on the thin end walls, thus differing from these layers in rye, which have indistinct pores on the side walls and none on the swollen ends of the cross cells. Intercellular spaces between the end walls are small or absent, whereas in rye they are often conspicuous.

The *cross cells* (Fig. 96) in extreme cases reach 200 μ in length, whereas in rye (Fig. 101) this dimension is rarely reached; furthermore, the average length in wheat is somewhat longer than in rye although little dependence can be placed on length in diagnosis.

Tschirch and Oesterle and some other authors, following their lead, consider that there are one or more cell layers with very thin walls between the hypoderm and the cross cells; other authors, notably Vogl, Moeller, and Collin, do not show such cells nor do we find them in the mature fruit, although we do find that the inner cells of the hypoderm have thinner walls than the outer and are more or less collapsed (Fig. 94).

Spermoderm (Figs. 94 and 95, *S*).—This coat consists of (1) an *outer light-colored layer* and (2) an *inner dark brown layer*, the cells in both being elongated, those in one layer crossing those of the other at nearly right angles, the direction in both cases being more or less diagonal to the axis

[1] Sitzgsb. bot. Ver. Prov. Brandenburg. 1882, **24**, 4; Anleitung zur Erkennung organischer und unorganischer Beimengungen in Roggen- und Weizenmehle. Leipzig, 1884, p. 15.

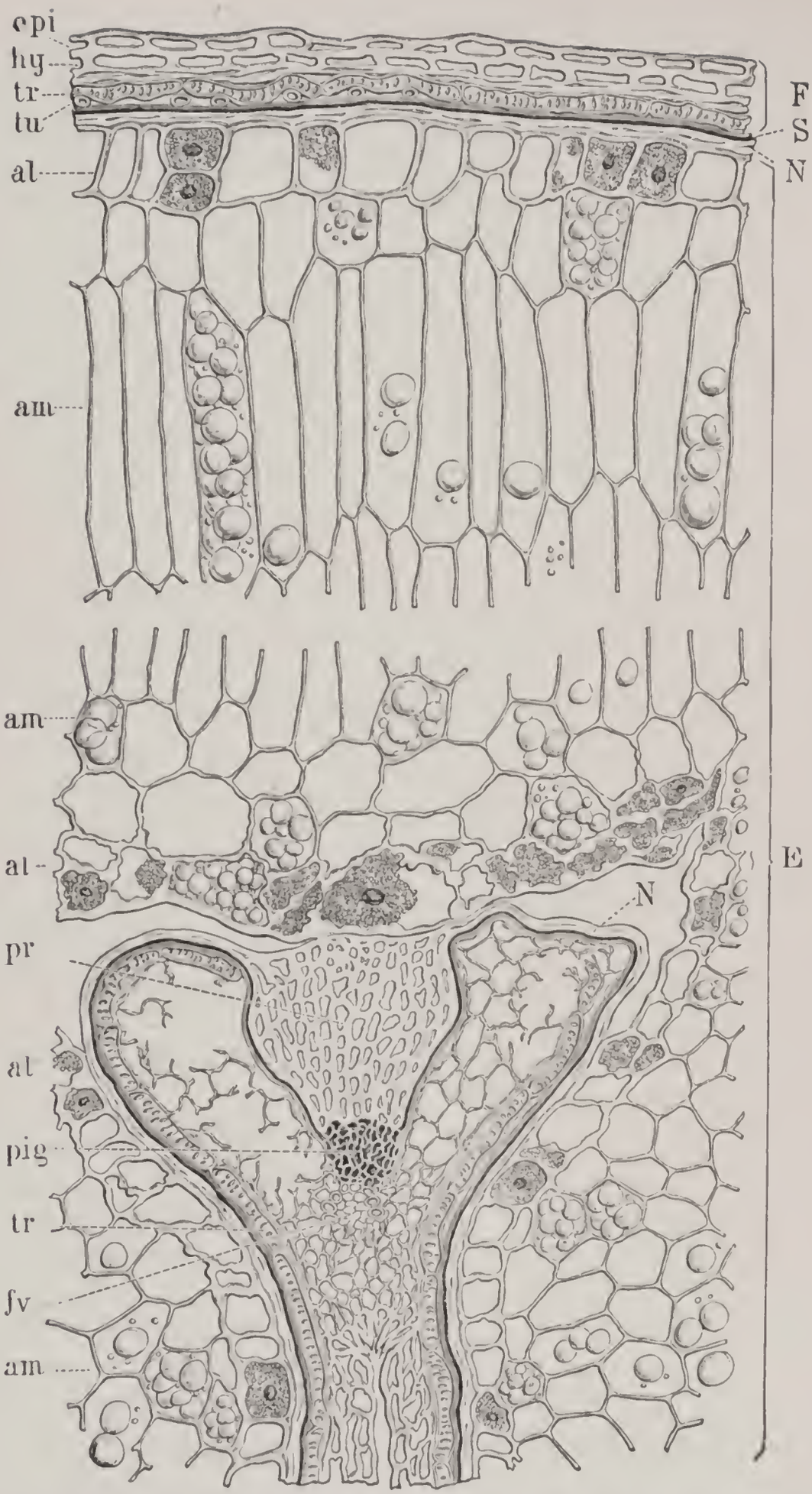


FIG. 94.—Wheat. Kernel in cross section showing tissues on dorsal side and about groove. *F* pericarp: *epi* epicarp, *hy* hypoderm, *tr* cross cells, *tu* tube cells. *S* spermoderm of light and dark layers, latter broadening along groove into *pig* pigment strand; *fv* bundle. *N* perisperm broadening along groove into *pr* perisperm strand. *E* endosperm: *al* aleurone cells, *am* starch cells. ×160. (A.L.W.)

of the kernel. In cross section the two layers form merely a light and dark line, but in surface view the delicate cell walls are evident.

The cells of the *outer layer* (*o*) are usually arranged side by side in rows much as in the cross-cell layer, but their delicate walls, appearing as narrow lines, contrast strongly with the thick pitted walls of the cross cells. In the *inner layer* (*i*) the cells break joints and show no decided tendency to an arrangement side by side in rows.

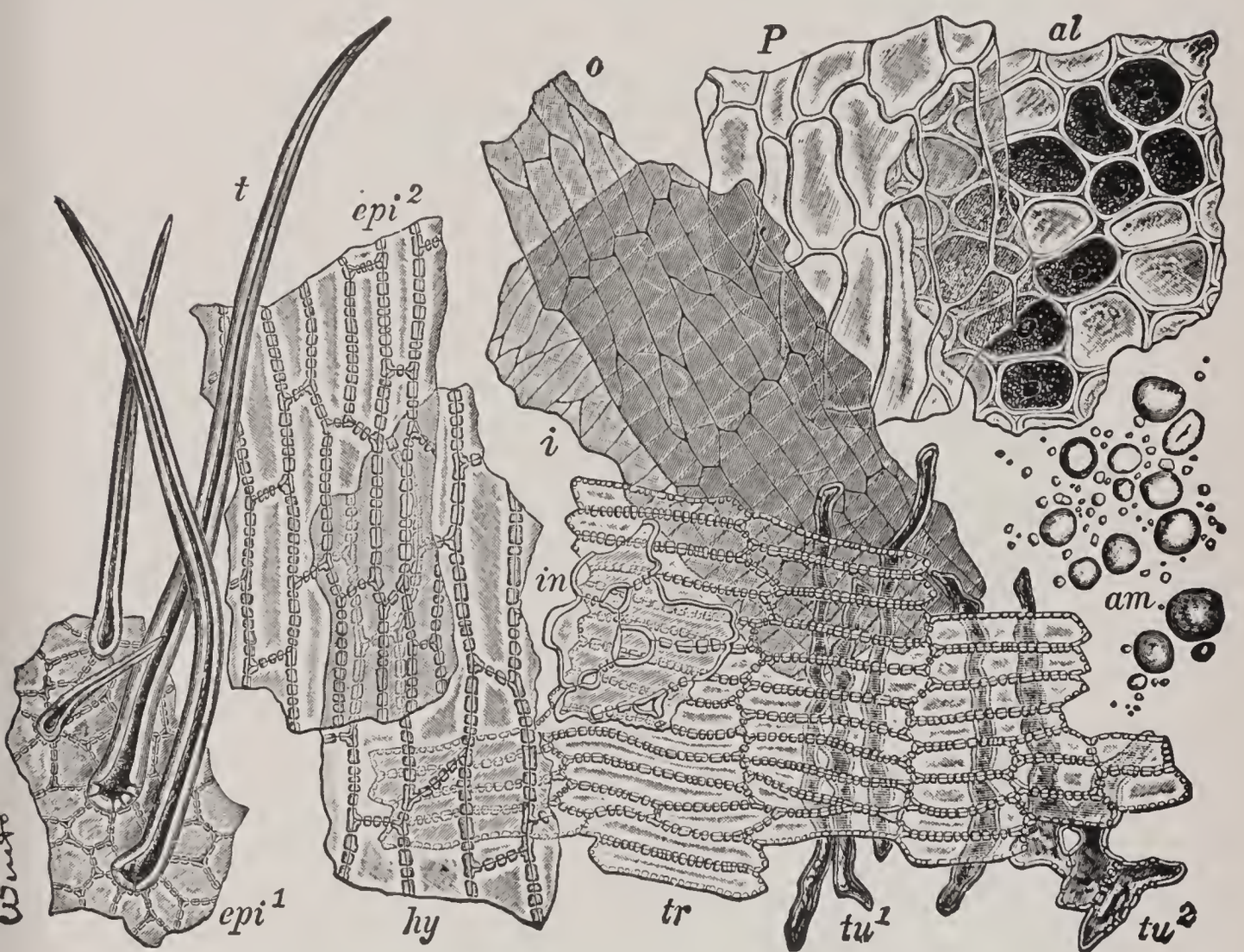


FIG. 95.—Wheat. Bran tissues in surface view. *epi*¹ epicarp with *t* hairs at apex; *epi*² epicarp on body of kernel; *hy* hypoderm; *in* intermediate cells; *tr* cross cells; *tu*¹ and *tu*² tube cells; *o* outer and *i* inner spermoderm; *P* perisperm; *al* aleurone cells; *am* starch grains. ×160. (A.L.W.)

Along the bottom of the groove (Figs. 94 and 97) the outer layer broadens and is more or less confluent with the pericarp. It is in this tissue that the *fibro-vascular bundle* (*fv*) of the raphe is embedded. The delicate spiral vessels of the fibro-vascular bundle may be teased out from this tissue with a needle. The inner layer is expanded in the groove into the *pigment strand* (*pig*) made up of small elongated cells with dark contents.

Körnicke and Werner[1] state that the color of common wheat is largely due to the shade of brown of the inner layer, although the cross cells of dark red wheats contribute somewhat to the color.

Perisperm (Fig. 94, *N*; Fig. 95, *P*).—In the development of the seed the only remnant of the ovule tissues on the body of the kernel is a single layer of glassy cells evident in cross section as a colorless band with thick outer and inner walls and lumen reduced to a faint line. Greenish[2] appears to mistake the lumens for tangential walls, since he refers to two rows of cells.

Without special treatment, the cells are seldom evident in surface preparations because of their transparent walls. Tiny sheets of this tissue may be removed from a soaked or boiled kernel, after previously stripping off the pericarp and spermoderm, using a lens for better observation. After doing this, which requires some patience, the delicate membranous skin should be stained with a suitable dye, such as safranin,

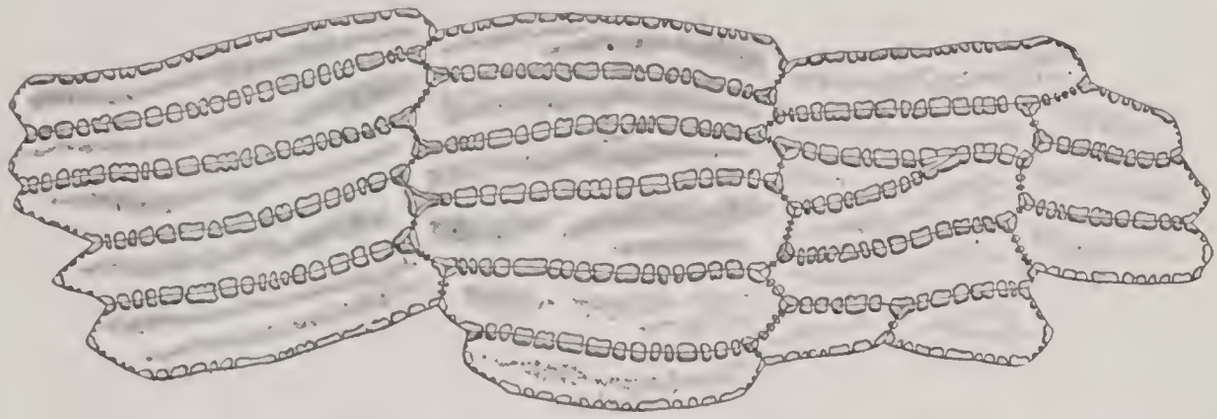


FIG. 96.—Wheat. Cross cells in surface view. ×300. (K.B.W.)

to bring out the cell walls. Moeller finds that by warming a whole kernel in 1 per cent sodium hydroxide and plunging into acetic acid the cell layers are loosened and the perisperm may be separated from the spermoderm in the scrapings by pressing sidewise on a slide beneath a cover glass. On soaking in a drop of chlorzinc iodine the perisperm takes on a blue color after a time and is readily distinguished from the brown or yellow spermoderm layers. By either method of treatment the cells are shown to be isodiameteric or longitudinally elongated, the polygonal form being modified by the waves of the thick walls.

In the bottom of the groove this layer expands into the *perisperm strand* which, although colorless, shows in both cross and longitudinal sections the numerous small thick-walled cells which are longitudinally elongated. In this region the perisperm tends to split away from the aleurone layer.

[1] Handbuch des Getreidebaues. Berlin, 1885, pp. 26–28.

[2] The Microscopic Examination of Foods and Drugs. London, 1903, p. 265.

Endosperm (Figs. 94 *E*, and 97).—Two distinct tissues form the endosperm: (1) the *aleurone cells* (*al*), also known as gluten cells and protein cells (the different names representing different views as to the nitrogenous contents), which are thick-walled and isodiameteric, forming a starch-free layer in most parts one cell thick, and (2) the *starch cells* (*am*) (the "flour cells" of Cobb), which form the great bulk of the endosperm and are characterized by the thin cell walls, numerous starch grains, and the protein contents invisible until brought out by special treatment.

The *aleurone cells* in cross section are nearly square or rectangular and have thick walls of uniform thickness, except at the bottom of the groove where they are irregular in shape and have knotty thickened walls formed by broad pores. The walls although thick are composed of cellulose. In this region about the groove some of the cells frequently contain starch, showing that there is no absolute differentiation in the two tissues of the endosperm. This point is further brought out by the fact that in some of the cereals at least, as for example broom corn, certain of the cells belonging to the outer layer of the starch parenchyma contain proteins but no starch.

Surface preparations show that the cells (Fig. 95, *al*) are rounded polygonal or quadrilateral. Wittmack [1] finds them to be larger, especially those with five to six sides, than those in rye, but this difference is not regarded as a dependable guide in diagnosis.

The cells contain a fine network of protein matter enclosing, according to Brahm and Buchwald,[2] fatty globules, the whole being yellowish in color. These minute globules or lumps, varying up to 3 μ in size, were formerly thought to be aleurone grains, and Von Höhnel[3] as well as Berthold[4] claimed that wheat and rye can be distinguished by their size, which in rye is only 1.5 to 2 μ. Wittmack,[1] Moeller[5] and others criticized this procedure even before the bodies were shown not to be aleurone grains at all.

In each cell is a nucleus, reaching 10 μ or more in diameter, which is often conspicuous without special treatment with a solution of methyl or iodine green or other nuclear stain. As shown by Körnicke and Werner [6] and by Benecke,[7] a blue coloration of the cell contents, such as is characteristic of rye, is never present. This is an important distinction.

[1] Loc. cit. (second ref.), p. 42.
[2] Z. Unters. Nahr.-Genussm. 1904, **7**, 12.
[3] Die Stärke und die Mahlprodukte. Kassel, 1882.
[4] Z. Waarenkunde, No. 1, 1883.
[5] Mikroskopie der Nahrungs- u. Genussmittel, 1 Aufl., 1886, p. 139.
[6] Loc. cit. pp. 26–28.
[7] Landw. Vers.-Stat. 1889, **36**, 337.

The general nature of the contents of aleurone cells of the cereals and the nomenclature has been discussed in the introduction to the group; there are, however, special points with reference to wheat which here deserve mention. Unlike those of other cereals, quite possibly the aleurone cells of wheat contain gluten as believed by the early investigators. There is no reason for believing that the protein contents differ from those of the adjoining starch cells which are known to contain gluten or rather its two constituents, gliadin and glutenin; in fact, Osborne [1] has shown that the protein extracted by dilute alcohol from shorts, which contains a large amount of the aleurone layer, has the same composition as that similarly obtained from flour. Even if the cells contain gluten, the name gluten cells is inappropriate since it suggests the gluten of flour which is derived almost exclusively from the starch cells.

As for the term aleurone cells, although our observations confirm those of Brahm and Buchwald that the so-called "aleurone grains" are not such at all but inclusions in a protein network, we are not disposed to abandon the term for this layer in the cereals. We have observed that in the aleurone cells of wheat the protein network, stained yellow with iodine, is not uniform in structure but contains minute granules which may be true aleurone grains. Somewhat larger granules, apparently of the same nature, occur in the outer layer of the starchy endosperm of wheat, as may be demonstrated by iodine staining, although these are not so conspicuous as those in sorghum.

Starch Cells (Figs. 94 and 95, *am*).—On the exposed parts of the grain (not in the groove) the starch cells of the outer layer are isodiametric and differ little in size and form from the aleurone cells but have much thinner walls. The next layer and several following consist of radially elongated cells. On both sides and at the bottom of the groove there are two or more layers of isodiametric cells.

The *starch grains* (Plate III, Fig. 25) increase in size from without inward, reaching the maximum in the first or second layer of elongated cells. The maximum size, 50 μ, is seldom reached—so seldom that grains over 50 μ in flour suggest the presence of rye flour. Most of the large grains in wheat are 30 to 40 μ in diameter. These large grains are lenticular in shape; when lying flat they are nearly but not absolutely circular; when lying on edge they appear as a lens in cross section. They may be made to change their position from flat side to edge by rolling the cover glass back and forth. Rings are very indistinct, even with careful illumination, and a hilum is practically absent although with polarized light the faint cross formed over the center indicates its position.

[1] The Proteins of the Wheat Kernel. Washington, 1907, p. 61.

The small grains are rounded or round-polygonal and vary from minute, scarcely measurable, up to about 10 μ. Transitions to the large grains are unusual. In bread the grains are swollen and much distorted.

Gluten as such is believed not to exist in the cells but is formed on making a dough and may be separated from the starch by kneading under a stream of water. It may also be obtained on a small scale as noted under Flour, below.

Cobb [1] demonstrates the presence of gluten as the medium surrounding the starch grains by heating water mounts of cells isolated after soaking kernels 10 to 20 hours in water, cutting in pieces, shaking in water, and collecting those found floating separately in the water. The heat causes agglutination of the protein about the gelatinous starch grain. The presence of gluten-forming proteins may also be demonstrated by treating with iodine cells isolated by Cobb's method or thin sections of the kernel.

A nucleus with its nucleolus may be demonstrated by nuclear stains but otherwise is not usually seen.

Embryo.—Fig. 97 shows the cellular structure of the embryo and the adjoining parts, whereas the corresponding part of Fig. 93, II, shows only the general morphology. In the *plumule* (*pl*), *plumule sheath* (*ps*), *hypocotyl* (*hy*), and *radicle* (*r*), the cells are very small and their contents are only faintly granular. The cell nuclei (not shown), however, are quite distinct, often occupying the larger part of the cell. In the *scutellum* (*sc*) (excepting the *palisade epithelium* (*pal*) and the *procambium bundle* (*pc*)), and its *ligule* (*ls*), the *coleorhiza* or root sheath (*rs*), and the *ligule* of the *hypocotyl* (*lh*) the cells are larger and the contents present a granular or reticulated appearance much like that of the aleurone cells.

Seen in the longitudinal section the form of the cells in the plumule, plumule sheath, and radicle is more or less quadrilateral, whereas in the ground tissue of the hypocotyl, scutellum, and root sheath the cells are polygonal. From the longitudinal section of the radicle alone (Fig. 98) one might conclude that both the outer layer (*dermatogen*) and the succeeding three or four layers forming the *periblem* or embryonic cortex are palisade cells, but since in cross section they are polygonal, they must be more or less tabular. The epithelium which bounds the scutellum on the endosperm side consists of true palisade cells. This is separated from the starch cells by a *hyaline layer* of compressed cells (*c*).

The *aleurone cells* are seen to follow along the top of the scutellum and the outer end of the plumule sheath nearly to its base; at the bottom

[1] Wisconsin Bur. Labor Ind. Statis. 1908, **13**, V, 742.

FIG. 97.—Wheat. Embryo and adjoining tissues in longitudinal section. Embryo: *pl* plumule, *ps* plumule sheath, *hy* hypocotyl with *lh* ligule, *sc* scutellum with *ls* ligule, *pal* palisade cells and *pc* procambium bundle of scutellum, *r* radicle, *rc* radicle cap, *rs* coleorhiza or radicle sheath. *fun* funiculus; *fv* bundle with spiral vessels; *epi* epicarp; *tr* cross cells; *pig* pigment strand of spermoderm; *pr* perisperm strand; *al* aleurone layer; *am* starch cells; *c* compressed cells forming a hyaline layer. ×40. (A.L.W.)

they follow around the curve until they are lost in the outer cell layer of the scutellum.

On the left of Fig. 97, the *perisperm strand*, the *pigment strand*, and the *fibro-vascular bundle* of the raphe are shown.

CHIEF STRUCTURAL CHARACTERS. — Kernel blunt, deeply grooved, hairy at tip, of a clear color whether light or dark (rye more pointed, dirty or greenish cast).

Hairs unicellular, usually with walls thicker than lumen (rye hairs usually with walls thinner than lumen); epicarp and hypoderm of longitudinally elongated distinctly beaded (porous) cells; cross cells of transversely elongated cells with distinctly beaded side and end walls (rye indistinctly beaded, end walls swollen). Spermoderm of two layers of

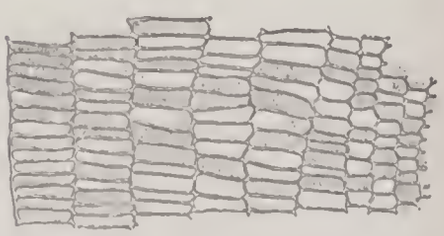


FIG. 98.—Wheat. Radicle in longitudinal section showing broad peripheral cells and narrow cells of central cylinder. ×160. (A.L.W.)

crossing thin-walled cells. Perisperm indistinct. Aleurone cells with faint yellow contents (rye usually blue); inner endosperm yielding

gluten on rubbing with water; starch grains large and small; large grains lenticular, usually 30 to 40 μ, seldom 50 μ (rye often 50 μ), with indistinct rings and hilum.

MICROSCOPY OF WHEAT PRODUCTS.—Uncooked Whole Wheat Products, such as *graham flour* and certain wheat breakfast cereals, although containing the same histological elements as the kernel, require quite different technique since it usually is not practicable to cut sections, thus necessitating dependence on surface preparations of bran fragments or on mounts of the powdered portion of the material.

Cooked Whole Wheat Products include *graham bread* and certain breakfast cereals prepared by steaming, crushing, and drying by a process similar to that used in preparing rolled oats (*rolled wheat*), by steam cooking, shredding, and baking (*shredded wheat*), or heating under pressure and suddenly releasing the pressure (*puffed wheat*), also whole kernels roasted or browned as a coffee substitute.

A moderate degree of cooking with steam or even baking or roasting does not necessarily destroy all the characteristics of the starch grains, although they swell and become distorted and also, if the heat is high, take on a burnt color to a greater or less degree depending on the conditions. If the problem offered is industrial or nutritional rather than diagnostic, the degree of swelling or alteration of the grains may furnish evidence as to the extent of cooking or ease of digestion.

Malted Whole Wheat Products.—These are commonly steam cooked as well as malted. If the malting is effected by the addition of the malt itself, certain barley elements may be looked for. The changes of the starch grains by malting, as well as by accidental sprouting, are quite different from those brought about by cooking, involving as they do the gradual solution of the starch grains by diastatic enzymes. The rings become quite distinct and fissures are formed as the action proceeds, as may be followed along by microscopical examination.

Decorticated Wheat Products.—*Grits*, commonly sold under trade names, contain the same elements as wheat flour. They are, in fact, granules of the endosperm which, on grinding, are converted into wheat flour.

Flour.—The term flour properly belongs to the finely ground, bolted, starchy endosperm of wheat, as obtained by the stone or roller process; Graham or true whole wheat flour is more exactly termed "meal." Although in the manufacture of white flour the whole kernel is first crushed, the processes of separation are so carried out as to remove all but traces of the bran coats, including the aleurone layer, and the germ.

Direct examination of the flour mounted in water shows myriads of

isolated starch grains, fragments of starch parenchyma, and a few hairs which found their way point first through the bolts like eels through a seine. Fragments of the bran coats occur in exceedingly small amount and when found are so obscured by the starchy matter as to show their characters indistinctly. If, however, foreign flours are present, their starch grains will be seen intermingled with those of wheat. The large grains of maize are recognized by their polygonal form, distinct hilum, and conspicuous polarization crosses. The starch of oat and rice flours is to a considerable extent in oval aggregates of many individuals. Although the large grains of rye flour are larger than those of wheat flour and the large grains of barley flour are smaller than those of wheat flour, in mixtures these distinctions are not sufficiently marked to reach positive conclusions, hence the need of recourse to the characters of the hairs and such fragments of the bran tissues as may be accumulated from a considerable amount of the flour. The distinction of wheat and rye hairs is noted under Rye.

The separation of the fragments of bran elements from the starch is readily accomplished by bringing to a boil a mixture of 2 grams of the flour, 2 cc. of sulphuric acid, and 200 cc. of water and allowing to settle. The deposit is mounted in a drop of 5 per cent sodium hydroxide and examined. This process, which is an abbreviation of the crude fiber method, permits the distinction of the cells of the outer bran coats, particularly the cross cells of wheat, from those of rye by their more distinct beading and the absence of swellings.

Schimper [1] brings to a boil in water alone and separates the scum which contains hairs and other bran tissues.

Fragments of the aleurone layer are obtained by the chloroform method. As carried out by Beneke,[2] 100 grams of flour are shaken thoroughly with 350 cc. of chloroform in a 500-cc. flask, filled to the neck with chloroform, again shaken, and allowed to stand 24 hours. Examination of the deposit shows that the contents of the aleurone cells of wheat are brown or yellow whereas those of rye are blue or olive-green.

The copious formation of gluten in wheat flour distinguishes it from all other cereal flours. This may be carried out on a small scale by rubbing a pinch of flour or scrapings from the endosperm of the kernel and a drop of water with a pen-knife or better by treatment according to the Bamihl test.[3] As carried out by Winton,[4] this latter test consists in rubbing 1.5 mg. of flour and a drop of very dilute eosin solution

[1] Nahr.- u. Genussm. Jena, 1900, p. 17.

[2] Landw. Vers.-Stat. 1889, **36**, 337.

[3] Pogg. Ann. 1852, 161.

[4] U. S. Dept. Agr., Bur. Chem. 1909, Bul. **122**, 217.

(1 : 5000) on a slide with a cover glass in such a manner as to effect thorough mixing without loss. The gluten rolls which form are made conspicuous by the absorption of the dye. The flour of no cereal other than wheat and the chaffy wheats yields any considerable amount of gluten by this treatment.

Bread.—Under this head may also be included all cereal oven products, whether raised by yeast, baking powder, or eggs, or without leaven of any kind. Examined directly, the starch grains, distorted by baking, are the conspicuous objects. Bran tissues are seen in the residue after treatment with acid as described under Flour. Naturally the chloroform and Bamihl tests are not applicable. Since American baking powder contains maize starch as a filler, the presence of a small amount of distorted maize starch grains may be attributed to this source, although in some commercial bakeries the sodium bicarbonate and the acid ingredient are added as such, thus dispensing with the filler. Yeast cells, killed by the baking, are present.

Milling Offals include screenings, shorts, bran, and low-grade or red dog flour, all of which are usually classed as cattle foods.

Screenings, consisting of immature, damaged, or broken wheat kernels, and weed seeds which may be mechanically separated, show the characters described in the appropriate sections. When the enormous wheat crop of the United States is considered in conjunction with its content of screenings, often reaching 3 or 4 per cent, the production of this little-thought-of by-product is evident. Upward of twenty weed seeds, described in this work, were studied chiefly because of their occurrence in wheat screenings with the view of better understanding their food value and their identification.

Wheat Bran is usually defined as consisting of the coatings of the wheat kernel, but as a matter of fact it contains a certain amount of starchy matter from the endosperm and its examination discloses the same elements as are found in whole wheat products. The addition to bran of such inferior products as ground corn cob, maize bran, peanut shells, coffee hulls, sawdust, etc., is now seldom practiced. Their detection is carried out with due regard to the microscopic characters noted under the appropriate heads.

The " mill run " of screenings is now commonly mixed with the bran and so branded.

Wheat Shorts or *Middlings* contains, in addition to bran fragments and starchy matter, the great bulk of the wheat germ, of which the small, more or less quadrilateral cells, particularly of the radicle, are characteristic. Removal of the fat by a suitable solvent renders these tissues more distinct.

In the examination of both bran and shorts the starch shows at a glance whether this is all from the wheat, rye, and barley group. Further examination involves the identification of bran tissues. Fragments of weed seeds are commonly present and sometimes supply information as to the section of growth.

Low-Grade or *Red Dog Flour* is a dark-colored flour with poor rising properties and chiefly for this reason is seldom used for human consumption. Although distinctly starchy, it contains an abundance of finely ground bran and germ elements.

Mixed Feed is an aptly named mixture of milling offals.

CHEMICAL COMPOSITION.—Early analyses of wheat are few but inaccurate; recent analyses are accurate but so numerous as to be bewildering. A general idea of the composition may be gained from the maximum, minimum, and average figures for American wheat analyzed prior to 1892 as compiled by Jenkins and Winton [1] and for American and foreign wheat exhibited at the World's Fair at Chicago in 1893 and analyzed under the direction of Wiley,[2] given in the table on the following page.

The separate averages of Winter and Spring wheat given in Jenkins and Winton's Compilation, although often quoted, are not representative, as only 13 samples of the former, mostly from regions other than the "Northwest" and Canada which now form the vast Spring wheat section, were analyzed, and none of the samples was from Kansas, Nebraska, Iowa, and Oklahoma, where both hard and soft Winter wheat are now extensively grown. The terms hard and soft wheat are more significant in commerce than those based on time of planting.

It should be noted that the range for protein of all samples as found by Wiley is about the same as reported by Jenkins and Winton, but the range for fiber and ash, which were doubtless more accurately determined than in the earlier analyses, is narrower. The minimum percentages for fat, however, are abnormally low.

König, in his Compilation,[3] reports analyses (many incomplete) of numerous samples from different countries and by various analysts. Following are given by countries the number of samples analyzed (in parentheses) and the range and average percentages of protein, (N × 6.25), the constituent of greatest significance, the averages being calculated to a water content of 13.37 per cent: northern, eastern, and central Germany, Winter wheat (54) 7.60 to 14.20, aver. **10.98**; Spring wheat (8) 8.90 to 15.20, aver. **11.23**; southern and western Germany,

[1] U. S. Dept. Agr., Off. Exp. Sta. Bul. **11**.

[2] U. S. Dept. Agr., Div. Chem. 1898, Bul. **13**, 1186.

[3] Chemie mensch. Nahr.-Genussm. Berlin, 1903, **1**, 413.

Composition of Wheat

	Samples	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
United States:							
J. and W.:	310						
Min.		7.10	8.05	1.26	64.84	0.44	0.80
Max.		13.95	17.15	3.93	78.66	3.05	3.57
Aver.		**10.52**	**11.87**	**2.09**	**71.90**	**1.79**	**1.83**
Wiley:	165						
Min.		7.11	8.58	0.28	66.67	1.70	1.40
Max.		14.53	17.15	2.50	76.05	3.72	2.35
Aver.		**10.62**	**12.23**	**1.77**	**71.13**	**2.36**	**1.82**
Canada:							
Wiley:	62						
Min.		9.38	8.23	0.41	65.92	1.75	1.38
Max.		13.98	16.10	2.32	75.36	3.12	2.00
Aver.		**11.69**	**12.25**	**1.80**	**70.31**	**2.26**	**1.69**
Other Countries:							
Wiley:	62						
Min.		8.52	8.58	0.73	67.01	1.87	1.67
Max.		12.97	14.52	2.26	76.14	2.89	2.04
Aver.		**11.47**	**12.03**	**1.73**	**70.66**	**2.23**	**1.73**

Winter wheat (42) 8.74 to 16.39, aver. **12.29**; Spring wheat (30) 8.14 to 19.56, aver. **14.95**; Austro-Hungary (18) 8.62 to 16.44, aver. **12.66**; Russia (33) 10.68 to 23.52, aver. **16.75**; England (15) 9.55 to 12.36, aver. **10.90**; Scotland (16) 7.07 to 13.05, aver. **10.58**; France (53) 9.17 to 21.50, aver. **12.64**; Denmark (29) 8.44 to 13.75, aver. **11.50**; Spain (9) 9.74 to 20.89, aver. **12.45**; Africa (20) 8.20 to 15.21, aver. **11.18**; India (8) 9.43 to 12.99, aver. **10.99**; Japan (4) 12.01 to 16.44, aver. **13.31**; and Australia (4) aver. **10.16**.

Snyder [1] states that the protein of wheat may fall as low as 8 per cent and run as high as 20 per cent.

Relation of Physical Characters to Composition.—It is well known that the horny part of the endosperm is richer in protein than the starchy, and it naturally follows that the hardness of the kernel determines in large degree the protein-richness of the wheat. Snyder notes that both the flinty appearance and the dark color of the cross section are indications of protein-richness. He found that heavy-weight glutinous kernels of six samples contained 15.56 per cent of protein, whereas the heavy-

[1] Minnesota Agr. Exp. Sta. 1904, Bul. **85**, 179.

weight starchy kernels contained but 13.69 per cent. Light-weight and shrunken seeds contained a higher percentage (16.17) than either, but these were not suited for milling or planting. He further found that large perfect kernels contained on the average 1.15 per cent more protein than the small perfect kernels of the same variety and sample. The composition of the ash of heavy and light weight kernels is noted below.

For the crops of 1922, 1923, and 1924, Mangels and Sanderson[1] noted a positive correlation between protein content and dark, hard kernels. Later studies by Mangels[2] brought out considerable seasonal variation and in some cases a low degree of correlation. As an index of wheat quality the dark-kernel content was found to be of questionable value and was being superseded by the actual protein test.

Changes in Composition During Ripening.—Teller's series of analyses of Arkansas wheat, harvested at different stages of ripening beginning with the time of setting, illustrate well the profound changes which take place during the early stage.[3] Of the analyses of 13 samples collected at intervals of three days and dried on the straw the first (I) and last (XIII) and two intervening (III and IV) are here given:

Composition of Wheat at Different Stages of Growth (Teller)

	Water	Pure protein	Amides	Fat	Dextrins	Dextrose	Sucrose	Starch *	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
I.....	6.75	11.34	10.85	14.64	6.80	1.69	3.12	15.61	12.46	9.91	6.83
III....	13.50	15.39	3.30	4.54	3.84	0.62	2.68	28.67	13.09	8.90	5.47
IV.....	13.60	12 31	0.75	2.49	2.60	0.10	1.78	48.75	10.37	4.41	2.84
XIII...	15.00	12.14	0.35	2.57	2.46	....	1.46	53.65	7.43	2.87	2.07

* Includes undetermined.

Shutt[4] found that one variety, Garnet, cut at the late milk stage, contained on the water-free basis more protein and ash than at later stages; another variety, Reward, reached its maximum in protein content at the firm dough stage.

Relation of Soil Fertility to Composition.—Some of the leading agricultural investigators, such as Lawes and Gilbert in England, Schindler in Germany, Shutt in Canada, and Wiley in the United States, have regarded the nature of plant food in the soil and the application of fertilizers as minor factors affecting the composition of the grain. On

[1] Cereal Chem. 1925, **2**, 107.
[2] J. Agr. Res. 1927, **34**, 157.
[3] Eighth Int. Cong. Appl. Chem. 1912, **13**, 273.
[4] Canada Dept. Agr., Rep. Dom. Chem. 1930, p. 16.

the other hand, experiments by Ritthausen and Pott [1] and the more recent extensive studies of Colorado wheat by Headden [2] show that nitrate of soda materially increases the protein content of the grain, thus favoring the formation of a hard flinty kernel. Headden also found that nitrate depresses the phosphorus content.

Proximate analyses of three varieties of wheat from the unfertilized check plot of one of Headden's three series, as obtained in the years 1913, 1914 and 1915, are given in the following table. These figures show a decrease of protein and also of phosphorus in the grain from year to year.

Composition of Wheat Grown Three Successive Years without Fertilizer (Headden)

	Water	Protein	Fat	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%
Defiance:							
1913.....	11.27	12.14	1.78	1.35	61.83	2.57	1.70
1914.....	8.92	10.46	1.91	1.06	63.14	3.57	2.02
1915.....	9.95	9.16	1.98	1.05	60.17	3.91	1.91
Red Fife:							
1913.....	10.63	14.43	1.87	1.15	61.88	2.76	2.05
1914.....	8.49	10.22	1.90	1.22	63.14	2.96	1.95
1915.....	10.09	8.38	2.06	0.76	62.04	3.31	2.00
Kubanka:							
1913.....	11.33	12.05	1.80	1.44	63.37	2.86	1.97
1914.....	9.64	9.98	1.95	1.39	62.59	3.01	1.69
1915.....	10.90	9.52	1.90	0.91	59.78	2.95	2.00

Headden also in each case determined the different forms of nitrogen, the results for Defiance, Red Fife, and Kubanka in the year 1913, being respectively as follows: amide nitrogen 0.052, 0.094, and 0.052, albumin nitrogen 0.168, 0.238, and 0.224, gliadin nitrogen 0.870, 0.898, and 0.819, glutenin nitrogen 1.039, 1.301, and 1.019; total nitrogen 2.130, 2.531, and 2.114 per cent. The decrease in nitrogen during the ensuing years, also the increase due to nitrate fertilization, was rather evenly distributed among the different forms.

Percentages of inorganic constituents corresponding to the percentages of ash in the above table are tabulated under the head of Mineral Constituents, below.

[1] Landw. Vers.-Stat. 1873, **16**, 384.

[2] Colorado Agr. Exp. Sta. 1916, Bul. **219**, part III.

The following table of average results shows the principal effects of nitrate fertilization:

Composition of Wheat as Influenced by Nitrate Fertilization (Headden)
(Air-dry basis.)

	Protein	Starch	Wet gluten	Dry gluten	True gluten	Phosphorus
	%	%	%	%	%	%
1913:						
Without nitrate	12.53	62.19	25.85	10.65	7.58	0.453
With nitrate	14.17	60.93	31.24	12.55	9.11	0.413
1914:						
Without nitrate	9.42	64.02	23.90	9.91	6.91	0.398
With nitrate	11.61	61.96	30.28	12.43	8.67	0.368
1915:						
Without nitrate	8.95	61.35	21.34	8.84	5.67	0.383
With nitrate	11.50	58.07	29.89	11.74	7.87	0 369

The average excess of protein in the grain from plots fertilized with nitrate over all others without nitrate in 1913 was 1.64 per cent, in 1914, 2.19 per cent, and in 1915, 2.55 per cent.

As regards other fertilizers employed in Headden's experiments, it may be said that in general potash tended to suppress the nitrogen and produce "yellow-berry," that is, a yellow or white, mealy or half mealy, or spotted kernel, but it did not affect the phosphorus content; phosphatic fertilizers produced no marked effect. The author states that the proper ratio of nitrate-nitrogen to potassium is essential, too much of the former producing weak plants and shrunken, flinty berries.

Contrary to the view of Shutt [1] and of Le Clerc,[2] Headden was unable to find that irrigation tended to produce soft wheat. He observes that not all shrunken kernels are high in protein.

Tretiakov [3] in Russia increased the protein of Spring wheat from 13.48 to 16.13 per cent and the phosphorus of Winter wheat from 0.77 to 1.22 per cent by fertilizing with barnyard manure.

Influence of Climate on Composition.—The amount and distribution through the season of rainfall, sunshine, and heat influence greatly yield, quality, and composition. Excessive moisture or heat not only are directly unfavorable but they also encourage fungous or insect parasites

[1] Canada Dept. Agr. Exp. Farm. Rep. 1903-9, p. 140.
[2] U. S. Dept. Agr., Bur. Chem. 1910, Bul. 123.
[3] Trudy Poltav. Selsk. Khoz. Opytn. Stantsii, 1913, p. 28.

which in turn influence composition. Frosting of the immature kernels prevents further development.

Moisture.—In accord with earlier investigators, Shutt [1] emphasizes that climatic conditions exert more potent influence than soil fertility. He calls particular attention to the low protein and high starch content of the soft wheat produced on newly cleared land, the characters of which he shows are due to excess of moisture, thus prolonging the growing season. Grown on Summer fallow land with low moisture content, seed wheat with 11.11 per cent of protein (N × 5.7) produced a crop with 12.62 per cent, whereas on newly cleared land the crop contained only 9.93 per cent. During the next year [2] he verified his conclusion by growing wheat on irrigated and non-irrigated land, producing on the latter Summer and Winter grain with respectively 2.15 and 1 per cent more nitrogen than that produced on the former. The ideal condition for high protein content he believes is where a supply of moisture during the earlier part of the season sufficient to bring the crop to full growth is followed by hot weather during ripening of the grain.

C. H. Bailey [3] notes in his study of Minnesota wheat for 1911 that the increase of rain during the growing season caused a regular decrease in the protein of the flour made from the wheat. Commenting on experiments of the next year,[4] he makes the following significant statement: "The variations in the composition and quality of wheat of the same varieties and types grown in different seasons, or in different localities the same year, are attributable principally to varying climatic conditions rather than to the fertility of the soil."

Frost.—Shutt[5] found that frosted wheat is higher in nitrogen than sound wheat. This is due to an excess of non-albuminoid nitrogen which in his experiments ranged in sound wheat from 0.08 to 0.14 per cent, in frosted wheat from 0.06 to 0.23 per cent, and in badly frosted wheat from 0.21 to 0.58 per cent.

In cooperation with Saunders,[6] Shutt studied the bread-making value and composition of Canada wheat of seven grades, grown during the year 1907, the first three grades being practically free from frosted kernels, the last four within creasing amounts of kernels thus damaged. The year was characterized by excessive rain and cold during the growing season and early frosts. Analyses of the wheat, although somewhat irregular, showed a higher average protein content (14.04 per cent)

[1] Canada Dept. Agr. Exp. Farm. Rep. 1907–8, p. 135.
[2] Rep. 1908–9, p. 140.
[3] Minnesota Agr. Exp. Sta. 1913, Bul. **131,** p. 42.
[4] Bul. **143,** p. 58.
[5] Loc. cit., p. 140.
[6] Canada Cent. Exp. Farm. 1907, Bul. **60.**

in the frosted samples than in the frost-free samples (13.51 per cent). The fat, ash, and fiber were also somewhat higher, and the nitrogen-free extract was correspondingly lower. The yield of straight flour ranged from 65 per cent in No. 1 Hard to 50.5 per cent in No. 6 Commercial Grade, and the volume of the loaf made from the flour from 492 to 363. No marked difference in the average percentage of protein in the flour from the sound seed and from the frosted seed and only a slightly greater average amount of fat, fiber, and ash in the latter were found on analysis; determinations of water-soluble nitrogen, potash, phosphoric acid, and sugar, however, brought out a marked excess of these constituents in the flour from frosted wheat, as is shown in the following table:

WATER-SOLUBLE CONSTITUENTS OF FLOUR FROM SOUND AND FROSTED WHEAT (SHUTT)

	Nitrogen	Ash	K_2O	P_2O_5	Sugar total	Sugar direct *	Sugar inverted †
	%	%	%	%	%	%	%
No. 1 Hard	0.32	0.34	0.15	0.13	4.10	1.96	2.14
No. 1 Northern	0.33	0.40	0.17	0.14	4.68	2.73	1.95
No. 2 Northern	0.34	0.32	0.15	0.12	3.66	1.87	1.79
No. 3 Northern	0.34	0.44	0.18	0.13	5.22	3.12	2.10
No. 4 Commercial	0.36	0.43	0.18	0.13	6.05	3.62	2.43
No. 5 Commercial	0.36	0.49	0.20	0.17	6.06	3.63	2.43
No. 6 Commercial	0.39	0.52	0.20	0.15	6.59	4.07	2.43

* Calculated as maltose.
† Calculated as sucrose.

Shaw [1] found in experiments in California that the protein and gliadin of the crop are increased by selection of seed of approved varieties with high nitrogen content, late seeding, cool weather, which retards growth, decreasing water content of soil, and late cutting.

Varietal Differences.—By scientific breeding, varieties are developed with special characters, such as high yield, resistance to drought, frost, and disease, and desirable milling properties, such as gluten content and quality. Deterioration of varieties must be continually guarded against by careful seed selection. Breeding for high starch content with the view of starch manufacture is not necessary in the United States, where maize is better suited for this industry.

[1] Univ. California Pub. Agr. Sci. Ser. 5, 1, 63.

Respiration.—Duvel [1] and C. H. Bailey and Gurjar [2] have shown that respiration of stored grain and the consequent carbon dioxide formed increase with the water content. The last-named authors found that the increase of carbon dioxide was gradual up to 15 per cent, then rapid from 15 to 17 per cent. Hard wheat respired slightly more rapidly than soft wheat, and shriveled, frosted, and dampened wheat somewhat more rapidly than normal. Bailey and Gurjar in a later paper [3] show that the most active respiration takes place in the embryo and increases on sprouting.

Wheat Flour and By-products.—Milling is a mechanical process having for its purpose primarily the separation of the endosperm from the embryo (germ) and bran coats and secondarily fine commutation. No clear idea of the nature of the products can be obtained without a comparison of structure of the kernel and the chemical composition of the different parts. A perfect separation into the morphological groups is not possible, but patent flour of high grade represents with reasonable accuracy the inner endosperm. Embryo and bran, even if well dusted, still contain starchy matter from the outer endosperm which cannot be removed mechanically, but analyses of these and the patent flour such as the following by Teller,[4] with due allowance for contamination, are highly instructive and dovetail with observations made under the microscope. It is indeed most unfortunate that the extensive investigations on the proteins, fats, and carbohydrates of this cereal have not been made in conjunction with equally extensive studies of structure and micro-reactions.

Composition of Patent Flour, Germ, and Bran (Teller)

	Water	True protein	Amides	Fat	Dextrins	Dextrose	Sucrose	Starch	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
Flour..	12.50	11.23	0.15	1.38	5.53	trace	0.35	68.75	2.60	0.10	0.40
Germ..	7.80	25.87	2.65	11.40	7.00	trace	14.60	13.72	4.90	1.35	4.70
Bran...	11.80	14.65	0.95	3.80	1.85	....	4.60	16.30	23.73	11.30	5.00

The above figures for protein represent the true protein obtained by subtracting the per cent of amide from that of total nitrogen and multiplying by 6.25. The flour (patent), germ, and bran contained,

[1] U. S. Dept. Agr., Bur. Plant Ind. 1904, Bul. **53**, 90.
[2] J. Agr. Res. 1918, **12**, 685.
[3] J. Biol. Chem. 1920, **44**, 5.
[4] Eighth Int. Cong. Appl. Chem. 1912, **13**, 277.

respectively: total nitrogen 2.00, 5.07, and 2.76; starch, undetermined and error (by difference) 65.76, 19.73 and 22.32 per cent.

In ordinary milling practice more than one grade of flour and more than two by-products (bran and germ) are obtained. Even if the flour is milled as a "straight" containing the entire bread-making part of the kernel, the "red dog" flour, suited only for cattle feed, is obtained as a fine by-product. However, there may be more than one grade of "patent" and one or more grades of "clear," that is, inferior quality flour. The "shorts" containing the greater part of the embryo, also known as "middlings" or "fine bran," may be marketed separately or mixed with the bran to form "mixed feed."

The following analyses of Snyder[1] are of representative products from the same wheat. Of course the straight and the four grades of patent and clear could not be obtained from the same milling, as the former contains all or part of the latter.

Composition of Wheat Products of Same Milling (Snyder)

	Water	Protein (N×5.7)	Fat	N-f. ext. and fiber	Ash	Acid calc. as lactic
	%	%	%	%	%	%
First patent flour	10.55	11.08	1.15	76.85	0.37	0.08
Second patent flour	10.49	11.14	1.20	76.75	0.42	0.08
Straight flour	10.54	11.99	1.61	75.36	0.50	0.09
First clear flour	10.13	13.74	2.20	73.13	0.80	0.12
Second clear flour	10.08	15.03	3.77	69.37	1.75	0.56
"Red dog" flour	9.17	18.98	7.00	61.37	3.48	0.59
Shorts	8.73	14.87	6.37	65.47	4.56	0.14
Bran	9.99	14.02	4.39	65.54	6.06	0.23
"Entire-wheat" flour	10.81	12.26	2.24	73.67	1.02	0.32
Graham flour	8.61	12.65	2.44	74.58	1.72	0.18
Wheat	8.50	12.65	2.36	74.69	1.80	0.18

Proximate analyses by Sullivan and Near of wheat and its milling products are given below in conjunction with ash analyses.

The composition of typical hard and soft wheat flours, also the influence of age and bleaching with nitrogen peroxide on color, are shown in the table on the following page.

The gasoline color value, determined by a method proposed by

[1] U. S. Dept. Agr., Off. Exp. Sta. 1901, Bul. **101.**

Winton,[1] includes only the color associated with the fat—the bleachable color—and not the bran color.

Composition and Color Values of Flour from Hard and Soft Wheat (Winton)

(The figures, excepting gasoline color value, are percentages)

	Minnesota Hard Spring		Nebraska Hard Winter		Michigan Soft Winter	
	78% patent	22% clear	80% patent	20% clear	80% patent	18% clear
Water	13.74	13.26	13.33	12.85	13.22	12.62
Protein (N×5.7):						
Total	10.60	11.74	10.09	11.86	8.66	12.26
Alcohol-soluble	5.84	6.21	5.79	6.55	5.24	5.53
Salt-soluble	1.62	2.19	1.48	2.02	1.45	2.19
Gluten:						
Moist	36.93	38.76	30.48	42.50	20.23	31.24
Dry	12.48	13.41	9.85	13.08	6.97	10.55
Fat	1.09	1.98	0.85	1.32	1.11	1.77
N-f. ext	74.07	71.91	75.16	73.06	76.40	72.19
Fiber	0.06	0.26	0.18	0.24	0.19	0.27
Ash	0.44	0.85	0.39	0.67	0.42	0.89
Acidity calc. as lactic	0.10	0.23	0.08	0.16	0.11	0.25
Gasoline color value:						
Unbleached:						
New	2.00	2.00	2.63	2.50	1.43	1.61
Aged 10 weeks	1.78	1.82	2.12	2.17	1.22	1.49
Aged 20 weeks	1.20	1.34	1.36	1.68	0.80	1.20
Aged 30 weeks	0.72	0.88	0.70	0.82	0.56	0.72
Bleached:						
New	0.60	0.66	0.80	0.80	0.40	0.50

Wheat Embryo (Germ).—Analyses by Schulze and Frankfurt[2] and Kalning,[3] calculated to the dry substance, are tabulated on the following page.

Water.—As discussed in the preliminary chapter on cereals, the amount of water influences greatly the keeping qualities of the grain and its products. Flour being a highly refined product for discriminating human consumers, its deterioration is a matter of serious concern.

[1] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **137**, 144.
[2] Z. physiol. Chem. 1895, **20**, 535.
[3] Z. ges. Getreidew. 1917, **9**, 167.

Composition of Wheat Embryo

	Schulze and Frankfurt	Kalning
	%	%
Protein soluble in water	13.62	19.76
Protein insoluble in water	21.62	20.99
Fat	13.51	12.00
Lecithin	1.55	.....
Phytosterol	44.00	.....
Nitrogen-free extract	44.72	39.25
Raffinose	6.89	.....
Pentosans	.....	11.55
Reducing sugar	.....	4.07
Sugar after inversion	.....	18.56
Fiber	1.71	2.50
Ash	4.82	5.50*

* P_2O_5: total 2.52, water soluble 1.62 per cent.

Snyder and Sullivan[1] after exhaustive investigations have pointed out the errors due to faulty methods of determining water in flour, the fallacy of arbitrarily basing government standards on such methods, and the injustice of judging flour by the high results obtained by accurate methods as compared with standards based on faulty methods, such as oven drying in open dishes, yielding low results.

The low results by the open-dish method, once largely employed in the analysis of wheat products, are partly but not completely nor uniformly compensated for by the use of the conventional factor 6.25 instead of the more accurate factor 5.70.

Proteins.—Gluten, the rubbery substance obtained by kneading the dough of white flour under a stream of water, is neither a definite protein nor a definite mixture of proteins; nor is it all nitrogenous matter. According to Olson,[2] on the average about 75 per cent of the total nitrogen of the flour is obtained in the gluten, the amount being relatively greater if the flour is high in protein, since in low protein flour there is a mechanical loss due to "scattering." Mixed with the proteins are variable amounts of starch, ash, fat, and water. Whether weighed wet or after drying, the amount obtained varies greatly with the salts in the water used in washing and the manipulation.

The proteins of wheat and rye are similar and perhaps identical, as

[1] J. Ind. Eng. Chem. 1924, **16**, 741, 1163; 1925, **17**, 311; 1926, **18**, 272.

[2] J. Ind. Eng. Chem. 1912, **4**, 206.

might be expected in view of the close botanical relation of the two and the very slight difference in structure. Although the Bamihl test is valuable in distinguishing wheat from rye flour, it has been the experience of the writers that the latter often shows a small but unmistakable amount of gluten; on the other hand, wheat flour may yield only a small amount of gluten quite out of proportion to the protein content.

Endosperm Proteins.—These, forming the bulk of the gluten, are radically different from the embryo proteins. Taddei[1] found in gluten two substances, one soluble in alcohol, "gliadin," and one insoluble in alcohol, "zymon."

Ritthausen[2] found four proteins in the endosperm, three soluble in alcohol but insoluble in water, now known as *prolamines* or *gliadins*, and one insoluble in alcohol but soluble in dilute alkali or acid, now known as *glutenin*, a *glutelin*, which he named *gluten-casein*. The names he assigned to the prolamines and the strength of alcohol in which they dissolve are: *gluten-fibrin* 80 to 90 per cent, *gliadin* 60 to 70 per cent, and *mucedin* 30 to 40 per cent.

Osborne and Vorhees [3] found only two proteins present in considerable amount in the endosperm: one prolamine, *gliadin*, soluble in 70 per cent alcohol, and one glutelin identical with Ritthausen's gluten-casein to which, at the suggestion of S. W. Johnson, under whose direction the study of proteins was undertaken, he gave the name *glutenin*. The specific rotation of wheat gliadin in 80 per cent alcohol, determined by Osborne and Harris,[4] is $-92.28°$, and in 70 per cent alcohol, determined by Matthewson,[5] is $-91.95°$.

König and Rintelen [6] confirmed Ritthausen's conclusions that three prolamines are present in the alcohol extract; Osborne and Harris [7] repeated the work of Osborne and Vorhees and again found but one.

Csonka and Jones [8] obtained, from a 0.2 per cent sodium hydroxide extract by precipitation with ammonium sulphate added to about 0.018 and 0.18 saturation, respectively, two *glutelins*, α and β, both with the same isoelectric point (pH 6.45). Csonka, Horn, and Jones [9] give the following values at 20°, for the glutelins prepared as described above: α -85.1, β -76.6.

[1] Ann. Phil. 1820, **15**, 390.
[2] Die Eiweisskörper, etc. Bonn, 1872.
[3] Am. Chem. J. 1893, **15**, 392; 1894, **16**, 524.
[4] J. Am. Chem. Soc. 1903, **25**, 842.
[5] Ibid. 1906, **23**, 1482.
[6] Z. Unters. Nahr.-Genussm. 1904, **8**, 401.
[7] Am. J. Physiol. 1905, **13**, 35.
[8] J. Biol. Chem. 1927, **73**, 321.
[9] Ibid. 1930, **89**, 267.

Blish and Sandstedt [1] present evidence showing that the *glutenin* as separated and examined by previous investigators is not the substance that exists in wheat and flour but a product of irreversible alteration of a more complex substance. Comparison of results of several chemists and even of the same group of chemists shows that glutenin preparations present a much wider variation in total nitrogen, amide nitrogen, and arginine nitrogen than gliadin, attributable to unavoidable errors and losses in the process of separation. Two preparations of their own were made by the usual method of extraction excepting that in one (I) N/60 and in the other (II) N/5 sodium hydroxide was employed. Analysis gave the following widely different results:

	NaOH	Total N	Amide N	Basic N
		gram	%	%
I	N/60	0.1393	24.4	9.7
II	N/5	0.1093	18.1	13.1

A new method of preparation tentatively adopted is in substance as follows: crude gluten prepared by washing in the usual manner is finely macerated and mixed with a large volume of dilute acetic acid. After standing overnight a thoroughly dispersed, somewhat viscid solution, with starch and other impurities in suspension, is obtained. In lieu of filtering, which was found impossible, the solution is diluted with methyl alcohol to 65 to 70 per cent concentration and slowly centrifuged. To the highly opalescent solution sodium hydroxide is cautiously added, avoiding excess, until the *p*H is slightly below 7. The heavy glutinous precipitate, purified by dissolving and reprecipitating several times, is dried by means of alcohol and ether. It appears to contain about 17.5 per cent of nitrogen, and yields on hydrolysis about 22 per cent of amide nitrogen and 9 per cent of arginine nitrogen calculated in terms of the total nitrogen. Further investigation along the line suggested will doubtless modify the ideas of glutenins previously held and may materially extend our knowledge of proteins as a group.

Although Osborne and Vorhees separated and analyzed small quantities of *globulin* and *proteose* from wheat flour, Osborne [2] questions their occurrence in the endosperm since it was uncertain whether the embryo had been completely removed in the process of milling. Hoffman and Gortner [3] doubt the presence in any appreciable amount of true globulin or proteose in patent wheat flour.

[1] J. Biol. Chem. 1929, **85**, 195.

[2] The Proteins of the Wheat Kernel. Washington 1907, p. 108.

[3] Cereal Chem. 1927, **4**, 221.

Morishima [1] believes that there is but one protein in gluten, "artolin," and that gliadin and glutenin are merely derivatives.

Embryo Proteins.—Osborne and his co-workers found three proteins: (1) *leucosin*, soluble in water (an albumin), (2) a *globulin* similar to globulins of other proteins, and (3) one or more *proteoses.*

The *Ultimate Composition* of the different proteins as determined by Osborne and Vorhees [2] follows:

	Leucosin	Globulin	Gliadin	Glutenin	Proteose *	Proteose †
	%	%	%	%	%	%
Carbon	53.02	51.03	52.72	52.34	49.94	48.99
Hydrogen	6.84	6.85	6.86	6.83	6.80	6.85
Nitrogen	16.80	18.39	17.66	17.49	17.08	16.89
Sulphur	1.28	0.69	1.03	1.08	1.24	1.10
Oxygen	22.06	23.04	21.73	22.26	24.94	26.17
	100.00	100.00	100.00	100.00	100.00	100.00

* Insoluble in saturated NaCl.
† Soluble in saturated NaCl.

Csonka and Jones [3] in their preparations of α- and β-glutelin obtained the following results:

	α-Glutelin	β-Glutelin
	%	%
Nitrogen (water- and ash-free basis)	17.14	16.07
Sulphur (water- and ash-free basis)	1.59	.....
Ash (water-free basis)	0.14	0.61

It is obvious from the nitrogen content of gliadin and glutenin, which constitute the proteins of the endosperm, that the factor 6.25, based on a nitrogen content of 16 per cent, is inaccurate for flour. It is quite impracticable to use a different protein factor for each seed and seed product, but in the case of wheat flour and other products of the wheat endosperm the use of the factor 5.70 seems justifiable.

Percentages of Proteins in Wheat.—In fine meals prepared by grinding the entire kernels of Spring and Winter wheat, Osborne [4] found the

[1] Arch. exp. Path. Pharm. 1898, **41**, 348.
[2] Loc. cit.
[3] Loc. cit.
[4] The Proteins of the Wheat Kernel. Washington 1907, p. 103.

following percentages of the different proteins and of the nitrogen in the form of these proteins:

	Spring Wheat		Winter Wheat	
	Nitrogen	Protein	Nitrogen	Protein
	%	%	%	%
Leucosin or albumin (soluble in water)	0.066	0.39	0.060	0.36
Globulin (soluble in salt solution)	0.125	0.63	0.115	0.63
Gliadin (soluble in alcohol)	0.603	3.96*	0.688	3.91*
Glutenin (soluble in dilute alkali)	0.825	4.63*	0.735	4.17*
Coagulum	0.045	0.27	0.038	0.22
Proteose	0.034	0.21	0.079	0.43
From water washings of gluten	0.224	1.27*	0.155	0.83*
Total	1.927	11.41	1.870	10.60

* N×5.68.

The coagulum, like the leucosin, is soluble in water but unlike it does not precipitate on heating to 65° or just to boiling. It does, however, coagulate on long boiling of the solution. The proteose is soluble in water but does not separate on prolonged boiling. The globulin, as is true of the class, is insoluble in water but soluble in 10 per cent salt solution. Gliadin, a prolamine, is insoluble in both water and brine but soluble in 70 to 90 per cent alcohol. Glutenin, a glutelin, is insoluble in water, salt solution, and alcohol but soluble in dilute alkalies or acids.

Amino Acids of Wheat Proteins.—Kossel and Kutscher [1] determined the hexone bases in gliadin, but Abderhalden and Samuely,[2] employing Fischer's method, were the first to determine with any degree of completeness the kind and approximate amount of the mono-amino acids obtained by hydrolysis. Osborne and Clapp,[3] following the methods of Fisher, Kossel and Abderhalden, and their co-workers, repeated the work of the foregoing and extended it to other proteins. In the case of gliadin the sum of their results was 65.81 per cent, which although more than in the case of glutenin and leucosin left much to be desired. More recently Osborne and Guest,[4] using better methods, have obtained more accurate figures for valine, leucine, glutamic acid, proline, and trypto-

[1] Z. physiol. Chem. 1900, **31**, 165.
[2] Ibid. 1905, **44**, 276.
[3] Am. J. Physiol. 1906, **17**, 231.
[4] J. Biol. Chem. 1911, **9**, 425.

phane; and Osborne, Van Slyke, Leavenworth, and Vinograd,[1] using Van Slyke's method, have revised the figures for lysine and histidine. In the following table these revised figures have been introduced, making the total 86.33, the figures under glutenin and leucosin remaining as originally reported by Osborne and Clapp:

PRODUCTS OF HYDROLYSIS OF WHEAT PROTEINS (OSBORNE ET AL.)

	Leucosin	Gliadin	Glutenin
	%	%	%
Glycocoll	0.94	0.00	0.89
Alanine	4.45	2.00	4.65
Valine	0.18	3.34	0.24
Leucine	11.34	6.62	5.95
Serine	....	0.13	0.74
Cystine	....	0.45	0.02
Aspartic acid	3.35	0.58	0.91
Glutamic acid	6.73	43.66	23.42
Tyrosine	3.34	1.20	4.25
Phenylalanine	3.83	2.35	1.97
Proline	3.18	13.22	4.23
Tryptophane	present	1.00 *circa.*	present
Arginine	5.94	3.16	4.72
Lysine	2.75	1.21	1.92
Histidine	2.83	2.19	1.76
Ammonia	1.41	5.22	4.01
	50.27	86.33	59.68

Determinations, by Cross and Swain,[2] of tyrosine and tryptophane in gliadin and glutenin from different flours, following the Folin and Looney method, show:

	Gliadin				Glutenin			
	Idaho	Patent	Club	Forty-fold	Idaho	Patent	Club	Forty-fold
	%	%	%	%	%	%	%	%
Tyrosine	5.10	5.10	5.04	5.04	5.34	5.52	5.47	5.92
Tryptophane	1.11	1.19	1.03	1.13	1.59	1.61	1.55	1.61

[1] J. Biol. Chem. 1915, **22**, 259.

[2] Ind. Eng. Chem. 1924, **16**, 49.

Jones, Gersdorff, and Moeller [1] by improved methods secured the following results on wheat endosperm proteins:

	Gliadin		Glutenin
	I	II	
	%	%	%
Cystine	1.68	1.76	1.56
Tryptophane	0.70	1.09	1.72

The percentages of basic amino acids found by Csonka and Jones [2] in the two glutelins they separated follow:

	α-Glutelin	β-Glutelin
	%	%
Cystine	3.25	7.49
Arginine	5.83	3.05
Lysine	3.48	3.67
Histidine	2.76	5.75

Nitrogen Distribution in Wheat Proteins.—Although made at a time when the constitution of the proteins was not well understood, determinations made by Osborne and Harris,[3] showing the nitrogen distribution

Nitrogen Distribution in Wheat Proteins (Osborne and Harris)

	Leucosin (albumin)	Gliadin	Glutenin
	%	%	%
Humin N	0.43	0.07	0.19
Di-amino N	3.50	1.00	2.05
Mono-amino N	11.83	12.25	11.95
Amide N	1.16	4.34	3.30
Total N	16.92	17.66	17.49

[1] J. Biol. Chem. 1924, **62**, 183.

[2] Loc. cit.

[3] J. Am. Chem. Soc. 1903, **25**, 323.

in three groups, are of interest for comparison with the more detailed analyses.

Gortner and Blish[1] have found that tryptophane is largely responsible for the formation of humin which takes place during hydrolysis, although other amino acids act to a greater or less extent.

Determination of the nitrogen distribution in the gliadin, glutenin, and crude gluten of both strong and weak flour led Blish[2] to the conclusion that the individual proteins of both types of flour are identical in chemical constitution, also that the gliadin-glutenin ratio is much more nearly constant in flours of different baking qualities than had hitherto been supposed. He found, however, that the percentages of albumin and globulin show marked variation, and that the contents of ammonia nitrogen in the different proteins of the same flour differ so widely as to serve as an accurate indication of the amounts of the various proteins present. In obtaining the results shown below, Van Slyke's method as modified by Gortner was used, but no correction was made for the solubility of the bases.

NITROGEN DISTRIBUTION IN THE PROTEINS OF STRONG AND WEAK FLOUR (BLISH)

	Gliadin		Glutenin		Gluten		
	Strong	Weak	Strong	Weak	Strong	Weak	Weak
	%	%	%	%	%	%	%
Humin N	0.50	0.57	1.84	1.66	1.19	1.37	1.11
Cystine N	0.37	0.29	0.18	0.18	0.46	0.70	0.43
Arginine N	4.55	4.47	9.69	9.27	5.24	5.54	5.54
Lysine N	0.65	0.97	2.61	1.90	2.21	2.60	2.28
Histidine N	6.77	5.62	5.47	7.59	2.79	1.28	1.50
Amino N*	53.46	54.10	53.59	53.38	55.21	56.15	55.14
Non-amino N*	7.44	7.55	9.52	9.35	9.54	9.88	10.13
Ammonia N	26.13	25.90	16.50	16.17	22.87	23.19	23.69
	99.97	99.47	99.40	99.50	99.51	100.71	99.82

* In filtrate from bases.

In accord with Blish's results, so far as they show that the proteins of different types of flour are identical, are the results of Cross and

[1] J. Am. Chem. Soc. 1915, **37**, 1630.
[2] J. Ind. Eng. Chem. 1916, **8**, 138.

Swain,[1] who determined the nitrogen distribution by Van Slyke's method in the gliadin and glutenin of four flours from different wheats and of the gliadin of different mill streams. Differences in behavior of the flours are attributed to physical state rather than chemical constitution.

NITROGEN DISTRIBUTION IN GLIADIN AND GLUTENIN FROM DIFFERENT FLOURS (CROSS AND SWAIN)

	Gliadin				Glutenin			
	Idaho	Patent	Club	Forty-fold	Idaho	Patent	Club	Forty-fold
	%	%	%	%	%	%	%	%
Acid-insoluble humin N.	0.03	0.13	0.15	0.11	0.66	0.52	0.63	0.67
Acid-soluble humin N.	0.44	0.57	0.39	0.40	0.80	0.91	0.94	1.07
Phosphotungstic humin N.	0.23	0.20	0.13	0.14	0.49	0.37	1.20	0.86
Cystine N.	0.71	0.84	0.77	0.73	0.72	0.71	0.65	0.65
Arginine N.	4.89	5.06	5.21	4.78	10.10	8.17	9.23	12.94
Lysine N.	0.66	0.59	0.56	0.55	4.74	4.93	4.72	6.42
Histidine N.	5.54	5.99	6.41	5.84	7.06	9.22	11.42	6.20
Amino N*.	52.26	52.73	53.26	51.44	54.02	54.57	56.55	55.62
Non-amino N*.	4.44	4.55	5.52	5.65	3.66	3.81	2.64	3.98
Ammonia N.	26.79	26.40	26.20	26.20	15.62	15.98	14.17	13.11
	96.04	97.11	98.60	95.84	97.87	99.19	102.15	101.52

* In filtrate from bases.

In interpreting the above figures, due allowance should be made for the inaccuracies of some of the methods. More convincing that the proteins of the different flours are identical are perhaps the percentages of tyrosine and tryptophane, determined by the Folin and Looney method, which are given under the head of Amino Acids of Wheat Proteins.

From a single sample of patent wheat flour, Hoffman and Gortner[2] isolated gliadin and glutenin and two preparations each of albumin and

[1] Loc. cit.

[2] Cereal Chem. 1927, 4, 221.

NITROGEN DISTRIBUTION IN GLIADIN FROM DIFFERENT MILL STREAMS (CROSS AND SWAIN)

	Patent	Second crush	Clear	Third tailings	Residue
	%	%	%	%	%
Acid-insoluble humin N	0.10	0.14	0.12	0.15	0.64
Acid-soluble humin N	0.33	0.40	0.43	0.41	0.50
Phosphotungstic humin N	0.11	0.14	0.35	0.26	0.27
Cystine N	0.67	0.67	0.67	0.73	0.47
Arginine N	4.64	5.07	4.92	5.00	4.97
Lysine N	0.25	0.30	1.20	0.00	0.73
Histidine N	7.38	6.35	5.67	7.71	5.09
Amino N*	52.97	52.24	52.30	53.25	53.65
Non-amino N*	7.62	10.01	7.46	5.82	6.02
Ammonia N	26.38	26.10	26.40	26.70	25.70
	100.45	101.42	99.52	100.03	98.04

* In filtrate from bases.

so-called globulin. One of the albumin preparations was of doubtful purity, and certain experiences led them to doubt, as noted above, the presence of any appreciable amount of true globulin, hence these questionable results are not included in the following table:

NITROGEN DISTRIBUTION IN GLIADIN AND GLUTENIN FROM PATENT FLOUR (HOFFMAN AND GORTNER)

	Gliadin	Glutenin	Albumin
	%	%	%
Insoluble humin N	0.34	0.78	0.93
Soluble humin N	0.32	0.66	1.13
Cystine N	0.44	0.67	1.63
Arginine N	5.29	11.96	15.70
Lysine N	0.50	4.52	9.50
Histidine N	8.22	4.72	4.44
Amino N in filtrate	53.23	53.47	49.47
Non-amino N in filtrate	5.95	7.50	7.04
Ammonia N	25.90	13.56	10.67
	100.19	97.84	100.51
Total N in protein	17.54	17.20	16.73
Total sulphur in protein	0.76	0.96	3.42

Larmour [1] prepared glutelin from common wheat, durum wheat, spelt, emmer, and einkorn, as well as from other cereals, following a modification of Osborne's method, and determined the nitrogen distribution of each by Van Slyke's method. He designated each protein by a name suggesting its origin (duro-, spelta-, dicocco-, and monococco-glutelin) although he does not claim that each is a distinct chemical individual. Whether the differences in the percentages of the different forms of nitrogen which appear in the following table, allowing for impurities in the preparation and errors in the methods, are properly attributable to actual differences in the proteins, can be decided only by further investigation. The glutelins of common wheat and the closely related durum variety show a wider difference in histidine than is shown between any other two members of the series.

NITROGEN DISTRIBUTION IN GLUTELINS OF WHEAT AND CHAFFY WHEATS (LARMOUR)

	Common wheat	Durum wheat	Spelt	Emmer	Einkorn
	%	%	%	%	%
Humin N	1.70	2.49	5.02	4.63	6.04
Cystine N	0.40	0.88	0.41	0.75	1.04
Arginine N	10.90	11.00	13.43	13.03	11.86
Lysine N	5.83	3.48	7.80	6.02	4.82
Histidine N	1.67	5.84	2.80	4.80	2.44
Amino N*	58.15	54.47	56.35	54.41	56.66
Non-amino N*	5.39	9.01	5.72	4.93	6.60
Ammonia N	14.78	13.25	8.06	11.06	10.78
	98.82	100.42	99.59	99.63	100.24

* In filtrate from bases.

Results by Csonka and Jones [2] on the nitrogen distribution, calculated to the water- and ash-free basis, are shown on the next page.

Vickery [3] by mild acid hydrolysis of wheat gliadin obtained a precipitate which gave by Van Slyke's method the following nitrogen distribution: humin N absorbed by calcium hydroxide 0.52, humin N absorbed in amyl alcohol extract 0.17, cystine N 1.35, arginine N 9.34, histidine N 3.99, lysine N 2.75, amino N 67.72, non-amino N in the filtrate from bases 8.83, and amide N 4.55 per cent.

[1] J. Agr. Res. 1927, **35**, 1091.

[2] Loc. cit.

[3] J. Biol. Chem. 1923, **56**, 415.

	α-Glutelin	β-Glutelin
	%	%
Cystine N	1.76	5.43
Arginine N	10.95	6.10
Lysine N	3.09	6.85
Histidine N	5.50	6.17
Amide N	17.80	11.06
Amino N of filtrate	45.40	49.13
Non-amino N of filtrate	13.00	14.90

Bran Proteins.—Jones and Gersdorff [1] have taken a further step in the right direction by determining the kind and amount of proteins in the bran as distinguished from those of the inner endosperm, supplementing Osborne's work on the inner endosperm and the embryo. An exceptionally clean bran was selected, washed with cold water to remove adhering starch, and dried at a low temperature. Extraction with the usual protein solvents, including 0.5 per cent sodium hydroxide, removed 86.61 per cent of the total protein, of which 61.27 per cent was actually obtained in the form of isolated proteins, soluble respectively in water, salt solution, and alcohol, namely: albumin 16.64, globulin 13.62, and prolamine 31.01 per cent.

The *Ultimate Composition* was shown to be as follows:

Ultimate Composition of Wheat Bran Proteins (Jones and Gersdorff)

	Albumin	Globulin	Prolamine
	%	%	%
Carbon	53.21	53.43	54.25
Hydrogen	6.71	7.40	6.75
Nitrogen	15.42	17.76	15.35
Sulphur	1.35	0.91	1.35
Oxygen	23.31	20.50	22.30
	100.00	100.00	100.00

Amino Acids of Wheat Bran Proteins.—Jones, Gersdorff, and Moeller [2] obtained the following figures for cystine and tryptophane:

[1] J. Biol. Chem. 1923, **58**, 117.
[2] Ibid. 1924, **62**, 183.

	Albumin	Globulin	Prolamine
	%	%	%
Cystine	3.29	1.52	2.29
Tryptophane	4.76	2.85	1.37

Nitrogen Distribution in Bran Proteins.—Jones and Gersdorff,[1] by Van Slyke's method for free amino nitrogen and bases, Folin and Looney's method for cystine and tyrosine, and May and Rose's method for tryptophane, obtained the following results:

Nitrogen Distribution in Bran Proteins (Jones and Gersdorff)

	Albumin	Globulin	Prolamine
	%	%	%
Cystine N	3.29	1.52	2.29
Arginine N	10.04	14.13	4.41
Histidine N	2.57	2.76	0.84
Lysine N	4.51	11.84	2.45
Tryptophane N	4.76	2.85	1.37
Tyrosine N	4.20	3.69	3.38
Free amino N	2.84	6.59	1.88
	32.21	43.33	16.62

The lower nitrogen content of the prolamine of the bran as compared with that of wheat gliadin, the greater proportion of globulin to prolamine, and the differences in the percentages of the amino acids are noteworthy. In interpreting the results, due weight should be given to the thicker walls of the aleurone cells which hinder penetration by solvents—some more than others—also the morphological relation of the aleurone cells to the inner endosperm and the transition of starch cells to aleurone cells both as regards walls and contents, as brought out under Microscopic Structure.

Free Amino Acids, Acid Amides, and Polypeptides.—The following determinations were made by Jodidi and Markley [2] on four representative varieties of wheat grown in the United States, namely, Kanred

[1] J. Biol. Chem. 1925, **64**, 241.

[2] J. Am. Chem. Soc. 1923, **45**, 2137; J. Agr. Res. 1925, **30**, 989.

(hard red Winter), Fultz (soft red Winter), Marquis (hard red Spring), and Kubanka:

Distribution of Non-protein Nitrogen in Wheat (Jodidi and Markley)

	Acid Amide N	Amino Acid N	Peptide N
	%	%	%
In oven-dried kernel:			
Fultz	0.026	0.032	0.084
Kanred	0.053	0.066	0.111
Kubanka	0.052	0.041	0.155
Marquis	0.058	0.054	0.151
In total nitrogen:			
Fultz	1.46	1.47	4.67
Kanred	1.88	2.34	3.89
Kubanka	1.72	1.35	3.13
Marquis	1.91	1.77	4.89

Nitrogen Distribution in Wheat Foods.—The Van Slyke method, designed to separate the amino acids of pure proteins into several groups, has been applied by Nollau [1] and by Grindley and co-workers [2]

Nitrogen Distribution in Wheat and Wheat Products

(Parts of nitrogen in 100 of total nitrogen)

	Amide N	Humin N	Cystine N	Arginine N	Histidine N	Lysine N	Mono-amino N	Non-amino N	Total N
Wheat *	17.59	9.21	1.34	7.99	1.67	2.47	47.67	13.59 §	101.53
Wheat bran †	9.67	13.75	5.96	12.53	3.84	4.04	49.95	0.00	99.74
Wheat bran ‡	9.17	6.86	0.81	11.99	7.32	3.90	38.07	3.59 §	100.51 ‖
Wheat gluten †	22.53	1.01	1.91	7.61	5.57	0.51	49.05	9.76	97.95

* Grindley and Slater.
† Nollau.
‡ Hamilton, Uyei, Baker, and Grindley.
§ Includes proline, oxyproline, tryptophane, etc.
‖ Includes ether soluble N 0.04, alcohol soluble N 1.23, non-protein N soluble in cold 1 per cent trichloracetic acid in filtrate from colloidal iron 15.26, N lost in method of analysis 2.27.

to the determination of the total amino acids, free and combined as proteins, in cattle foods. Owing partly to the interference of carbohydrates, the results of different workers are far from concordant, as is

[1] J. Biol. Chem. 1915, **21**, 611.

[2] J. Am. Chem. Soc. 1915, **37**, 2762; 1923, **45**, 815.

indicated by some of the figures above. Notwithstanding the criticisms of Hart and Sure, Gortner, and others, Grindley believes that the results of the Van Slyke method applied to feeds are nearly if not quite as accurate as when applied to pure proteins and that this line of inquiry is destined to be of practical importance.

Fat (Ether Extract).—The fat of the embryo appears to be different from that of the remainder of the kernel, hence the distinction between wheat germ oil and wheat meal or flour oil. As obtained by milling machinery, the embryo contains about 15 per cent of fat, allowing for contamination with endosperm. Assuming that the embryo forms 3 to 4 per cent of the kernel, as stated by Maurizio on the authority of Haberlandt,[1] about 20 per cent of the fat of the kernel is derived from the embryo, the bran and the inner endosperm contributing somewhere around 40 per cent each. This calculation does not take into account the imperfect separation of bran and embryo and the possibility of a large amount of oil being squeezed out of the embryo in milling and absorbed by the bran or the starch of the endosperm.

Physical and Chemical Values.—Wheat germ oil, as examined by Frankforter and Harding,[2] was characterized by the following values: specific gravity at 15° C. 0.9292 to 0.9374, refractive index at 20° C. 1.4832, saponification number 187.4 to 190.3, and iodine number 115.6. It contained 2 per cent of lecithin. De Negri [3] found: specific gravity at 15° C. 0.9245, saponification number 182.8, iodine number 115.2, and acids as oleic 5.65 per cent. The fatty acids solidified at 29.7° C., melted at 39.5° C., and had an iodine number of 123.3.

Plücker,[4] in the examination of 10 samples of wheat flour oil, found lower iodine numbers than those given above for the germ oil, the range being 96.1 to 112.5. This is in accord with the experience of the writers, who have noted that the oil from patent flour has a lower number than that from clear flour, the latter being contaminated with more of the embryo tissue.

Ball [5] examined wheat germ oil and patent flour oil, obtained in both cases by ether extraction, with the results shown on the next page.

Ball also obtained the following on the germ oil: neutralization number of insoluble acids 205.73, of solid acids 228.94, of liquid acids 202.66; mean molecular weight of insoluble acids 272.72, of solid acids 245.08, of liquid acids 276.85.

[1] Getreide, Mehl und Brod. Berlin, 1903, p. 6.
[2] J. Am. Chem. Soc. 1899, **21**, 758.
[3] Chem. Ztg. 1898, **22**, 976.
[4] Z. Unters. Nahr.-Genussm. 1907, **14**, 751.
[5] Cereal Chem. 1926, **3**, 19.

	Sp. gr.	Refr. index	Sapon. No.	Iodine No.	Reichert Meissl No.	Polenske No.	Hehner No.	Ester No.	Acid No.	Unsap. matter
										%
Germ oil.	0.9249*	1.4686†	184.1	123.6	0.48	0.25	93.71	162.7	21.48	3.58
Flour oil.	0.9694‡	1.4714†	160.9	105.4	.....	.....	.....	.....	.....	2.51

* 25°/1°. † Temperature ? ‡ 28°/1°.

Wheat bran oil, examined by Stellwaag,[1] contained 2.09 per cent of lecithin. As the saponification number was 183.1, the bran probably contained the embryo.

Sterols.—Frankfurt in 1887 reported 0.44 per cent of " cholesterol " in wheat germ containing 13.51 per cent of total ether extract (crude fat). He further states that the melting point 132° C. corresponds with that of phytosterol (131 to 132° C.).

Burian [2] prepared an apparently homogeneous phytosterol, " sitosterol," from wheat and rye germ. The melting point of this sitosterol was 137.5° C., and of its acetate, 127° C. The " parasitosterol " from the mother liquors had a similar melting point, as did also the " sitosterol " of Ritter.[3]

Anderson and associates have thoroughly studied the sterols of the inner endosperm, bran, and embryo of the wheat kernel.

From wheat germ, Anderson, Shriner, and Burr [4] obtained 10 per cent of fat containing 4 per cent of unsaponifiable matter of which 65 per cent, equivalent to 2.6 per cent of the fat, was crude sterols. Calculated to the germ, the unsaponifiable matter amounted to about 0.4 per cent and the sterols to 0.26 per cent. They did not obtain a pure homogeneous *sitosterol* but mixed sterols which they showed to contain *dihydrositosterol* ($C_{27}H_{47}OH$), which conceivably was derived from bran and starchy impurities, and at least three sterols isomeric with ordinary sitosterol ($C_{27}H_{45}OH$), namely α-, β-, and γ-sitosterol. They were unable to secure the α and β compounds pure but did separate γ-sitosterol, the least soluble of the three, in the form of fairly pure colorless plates resembling those of sitosterol with the following properties: melting point 147 to 148° C.; specific rotation at 20° C. about $-42°$.

Anderson and Nabenhauer [5] extracted the fat from wheat endosperm (or rather inner endosperm) from which the bran and embryo had been

[1] Landw. Vers.-Stat. 1890, **37**, 133.
[2] Monatsh. Chem. 1897, **18**, 551.
[3] Z. physiol. Chem. 1902, **34**, 461.
[4] J. Am. Chem. Soc. 1926, **48**, 2987.
[5] Ibid. 1924, **46**, 1717.

separated as completely as possible. The total fat obtained by extraction with petroleum ether was 0.81 per cent; the unsaponifiable matter or crude phytosterol, 0.068 per cent. The latter, after being purified by crystallization from alcohol until snow white, had a melting point of 138.5° C. and a specific rotation at 20° C. in chloroform of −15.6°. It appeared to correspond to the sitosterol of Burian.

In a quantity of wheat bran used in further experiments, the same authors found 3 per cent of petroleum ether extract, which in turn contained 6 per cent of unsaponifiable matter equivalent to 0.18 per cent of the bran. In the unsaponifiable matter, dihydrositosterol, apparently identical with the saturated sterol of corn endosperm, was particularly abundant. Purified by repeated crystallization, it had a melting point of 144 to 145° C. and a specific rotation at 20° C. of +25.82°. Ordinary sitosterol was also present.

Carbohydrates.—Although starch is usually considered as practically the only carbohydrate of the so-called nitrogen-free extract, the soluble carbohydrates, present in small amount, play an important rôle in aging and bread-making. Usually the soluble carbohydrates are classified as sucrose, invert sugar, and dextrin, although other carbohydrates may be included under each. They occur chiefly in the embryo, and it is doubtless these that decompose first during respiration and spoilage.

Sucrose was separated from the embryo as such by Schulze and Frankfurt,[1] thus refuting the claim of several investigators that it is not present.

Raffinose was shown to be present in the embryo by Richardson and Crampton,[2] increasing on sprouting. Frankfurt[3] reports 6.89 per cent of raffinose and 24.34 per cent of soluble carbohydrates in wheat embryo.

O'Sullivan[4] describes two dextrin-like substances, *α-* and *β-amylan*, but their amount is small and their identity is somewhat uncertain.

Unripe wheat may contain *secalose*, or *β-levulin*, first obtained by Schulze and Frankfurt from unripe rye and oats.

The cell walls of the embryo and inner endosperm are pure cellulose or at least are non-lignified. *Lignin* occurs in all the pericarp layers.

Wheat bran is characterized by its *pentosans* which, according to Teller,[5] constitute 23.73 per cent of the air-dry material. The pentosans appear to consist of a mixture of an araban, the metaraban of Steiger

[1] Ber. 1894, **27**, 62.
[2] Ibid. 1886, **19**, 1180.
[3] Landw. Vers.-Stat. 1896, **47**, 449.
[4] Chem. News 1880, **44**, 258.
[5] Loc. cit.

and Schulze,[1] and xylan. As in the case of the proteins it is unfortunate that the pericarp and aleurone layers have not been separated by painstaking dissection and separately treated, the changes in the cell walls being noted under the microscope.

Stone [2] obtained the following amounts of carbohydrates in air-dry Winter and Spring wheat, respectively: sucrose 0.48 and 0.66 per cent, invert sugar 0.08 per cent and none, "dextrin," 0.25 and 0.38 per cent, pentosans 4.54 and 3.94 per cent, fiber 2.68 and 2.26 per cent. His results for starch are obviously miscalculated or misprinted.

Krug [3] has determined the invert sugar, sucrose, and dextrin in wheat and wheat products with the following results, which are in substantial agreement with Stone's figures:

Soluble Carbohydrates in Wheat and Its Products (Krug)

	Invert sugar	Sucrose	Dextrin
	%	%	%
Wheat	0.027	0.330	0.160
Graham flour	0.038	0.382	0.210
Self-raising wheat flours	0.000	0.056	0.080
Miscellaneous wheat flours	0.003	0.098	0.130
Common market wheat flours	0.021	0.288	0.210
Bakers' and family flours	0.027	0.190	0.220
Patent wheat flours	0.002	0.085	0.200

Phosphorus-Organic Compounds.—An analytical study of the products of two Italian mills with special reference to the phosphorus compounds was made by Masoni.[4] Since the milling processes employed are somewhat different from those of American mills, the designations in the following table are in some cases the nearest equivalents based on the analyses.

The author calls attention to the increase in organic phosphorus, both total and in the different forms, from the highest grade of flour to the bran, paralleling the increase in ash and fat. He further notes that phytin and nuclein are not materially altered in bread-making but lecithin is destroyed to a considerable extent. In judging the nutritive value of flour and bread he believes that the phosphorus content should be given due consideration.

[1] Ber. 1890, **23**, 3110.
[2] U. S. Dept. Agr., Off. Exp. Sta. 1896, Bul. **34.**
[3] U. S. Dept. Agr., Div. Chem. 1898, Bul. **13**, 1207.
[4] Staz. sper. agr. ital. 1915, **48**, 385.

PHOSPHORUS DISTRIBUTION IN WHEAT PRODUCTS (MASONI)

	Milling yield	Water	Fat	Ash	Lecithin P_2O_5	Phytin P_2O_5	Nuclein P_2O_5	Total P_2O_5
	%	%	%	%	%	%	%	%
Stone Process:								
Cleaned grain		14.20	1.46	1.69	0.030	0.588	0.145	0.975
Flour, 1st grade	19	13.90	0.50	0.42	0.020	0.102	0.090	0.240
Flour, 2nd grade	25	14.10	0.74	0.56	0.018	0.180	0.110	0.358
Flour, 3rd grade	16	14.25	0.90	0.78	0.028	0.280	0.120	0.480
Flour, low grade	17	13.85	1.49	1.00	0.029	0.310	0.186	0.589
Shorts	8	14.60	2.09	2.48	0.040	0.810	0.150	1.428
Bran	17	14.55	3.35	5.68	0.041	1.997	0.200	3.122
Roller Process:								
Cleaned grain		15.05	1.66	1.76	0.032	0.609	0.130	0.860
Flour	70	15.66	0.68	0.48	0.026	0.110	0.100	0.264
Flour, low grade	5	14.20	1.40	1.32	0.026	0.231	0.150	0.480
Shorts, light	3	14.08	3.30	3.64	0.033	0.974	0.204	1.971
Shorts, dark	4	14.94	3.68	4.30	0.040	1.254	0.206	2.304
Bran	18	14.50	3.50	5.90	0.038	2.457	0.283	2.994

Lecithin.—In water-free wheat Schulze [1] reported 0.65 per cent of lecithin. More recent investigators have determined lecithin in wheat products—flour, germ, and bran. Only a part of the lecithin is extracted or expressed with the oil.

Frankfurt [2] found in wheat germ 1.55 per cent of lecithin; Alpers [3] found 2.49 per cent.

In wheat flour of different grades, Juckenack and Pasternack [4] adopted an average of 0.0225 per cent of lecithin phosphoric acid as representative of water-free wheat flour, although as high as 0.0435 per cent was noted. Using the conversion factor 11.4, these figures are equivalent to 0.257 and 0.496 per cent of lecithin. Masoni,[5] as noted above, found in flour of ordinary grades from 0.018 to 0.028 per cent of lecithin phosphoric acid, equivalent to 0.205 to 0.319 per cent of lecithin, and in wheat bran 0.038 and 0.041 per cent of lecithin phosphoric acid, equivalent to 0.433 and 0.467 per cent of lecithin.

Phytin.—The discoverer of phytin was Posternak, but it was Winter-

[1] Landw. Jahrb. Schweiz 1892, **6**, 72.

[2] Landw. Vers.-Stat. 1896, **47**, 449.

[3] Chem. Z. 1918, **42**, 37.

[4] Z. Unters. Nahrs.-Genussm. 1900, **3**, 13; 1904, **8**, 94.

[5] Loc. cit.

stein who first showed that it was an inosite-phosphoric acid. Patten and Hart [1] found that 86.5 per cent of the water-soluble phosphorus of wheat bran exists as a magnesium-calcium-potassium salt of a phospho-organic acid that may be split up into inosite and phosphoric acid.

Anderson in his earlier studies of phytin [2] isolated inosite mono-, di-, and tri-phosphoric acid but no true phytin (inosite hexaphosphoric acid). In later experiments [3] he found that the enzyme phytase, discovered by Suzuki, Yoshimura, and Takaishi,[4] was responsible for his early failure to find phytin, since that enzyme hydrolyzes the phytin in the dilute acid solution used in the process, forming inorganic phosphoric acid and a series of intermediate compounds. Using a higher strength of acid, that inhibited the enzyme action, he separated phytic acid and prepared several metallic salts. He concluded that phytic acid is inositol hexaphosphoric acid, $C_6H_{18}O_{24}P_6$ or $C_6H_6(O \cdot H_2PO_3)_6$.

Boutwell [5] believes that the modified Patten and Hart process,[6] followed by Anderson, was the cause of his difficulties. Employing the Clark process,[7] he prepared from wheat embryo phytin in the form of a crystalline calcium-magnesium salt—a new compound not agreeing in composition with any simple calcium-magnesium salt of inosite hexaphosphoric acid—free from inorganic phosphates. He concludes that the phytin present in the wheat kernel exists as salts of inosite phosphoric acid, and that the free phytic acid is an ester of inosite phosphoric acid.

Averill and King,[8] employing the Heubner and Stadler method,[9] obtained in wheat products the following percentages of phytin calculated as $C_6H_{18}O_{24}P_6$: wheat, 3 varieties, 1.16 to 1.36 per cent; wheat bran, 4.53 per cent; wheat flour, 8 brands, 0.68 to 1.28 per cent.

Rather [10] in his earlier work, found that bran as well as cottonseed meal yielded an inosite phosphoric acid richer in carbon but poorer in phosphorus than first proposed by Posternak, agreeing closely with the formula $C_{12}H_{41}O_{42}P_9$. His later work,[11] wherein he prepared crystalline strychnine and silver salts, showed substantial agreement with that of

[1] New York State Agr. Exp. Sta. 1904, Bul. **250**, 169.
[2] J. Biol. Chem. 1914, **18**, 425, 441; 1915, **20**, 463.
[3] Ibid. 1915, **20**, 475, 483, 494; 1920, **44**, 429.
[4] Bul. Col. Agr. Tokyo 1907, **7**, 503.
[5] J. Am. Chem. Soc. 1917, **39**, 491.
[6] Am. Chem. J. 1901, **31**, 564.
[7] J. Chem. Soc. 1914, **105**, 535.
[8] J. Am. Chem. Soc. 1926, **48**, 724.
[9] Biochem. Z. 1914, **64**, 422.
[10] J. Am. Chem. Soc. 1913, **35**, 890.
[11] Ibid. 1918, **40**, 523.

inosite pentaphosphoric acid, $C_6H_6(OH)(O \cdot H_2PO_3)_5$ or $C_6H_{17}O_{21}P_5$. This latter formula was adopted because it represented a theoretically possible compound. In the acid-soluble part of wheat shorts and bran Rather found that respectively 84 and 89 per cent of the phosphorus existed as inosite phosphoric acid and 8 and 3 per cent as inorganic phosphorus.

Nucleic Acid (Nuclein).—The embryo of wheat contains triticonucleic acid, similar if not identical to yeast nucleic acid, which was discovered by Osborne and Campbell [1] and further studied by Osborne and Harris,[2] Osborne,[3] and Osborne and Heyl.[4] Fresh commercial germ meal contains about 3.5 per cent of this nucleic acid, but the amount diminishes on aging. Elemental analysis indicates that the formula is $C_{41}H_{61}N_{16}P_4O_{31}$. It forms acid salts with alkali elements. On hydrolysis with acids it yields 1 molecule of guanine, 1 of adenine, 2 of uracil, and 3 of pentose for every 4 atoms of phosphorus; also cytosine as was found in the mother liquor by Wheeler and Johnson.[5]

Acidity.—The determination of acidity of the water extract of flour as a means of judging its grade was first proposed by Snyder.[6] The results roughly parallel those of ash but differ materially according to the temperature and time of digestion. Usually the acidity is calculated as lactic acid, although it is doubtful if any appreciable amount of this acid is actually present.

Results obtained by Swanson[7] show the unmistakable relation of acidity to soluble and total phosphoric acid and to amino acids. He found that raising the temperature from 25° to 40° and the time of digestion from 30 minutes to 2 hours greatly increased the percentage of both acidity and soluble phosphoric acid.

Collatz [8] states that the Greek official method prescribes that 85 per cent alcohol be used for extracting the acid. Markley and Bailey [9] found that with fresh flour the American method, employing a water extract, gave results more nearly correlated with the ash content than the Greek method.

Hydrogen Ion Concentration.—The range in hydrogen ion concentration of water extracts of wheat products is not sufficiently pronounced

[1] J. Am. Chem. Soc. 1900, **22**, 379.
[2] Connecticut Agr. Exp. Sta. Rep. 1901, p. 365; Z. physiol. Chem. 1902, **36**, 85.
[3] Am. J. Physiol. 1903, **9**, 69.
[4] Ibid. 1908, **21**, 157.
[5] Am. Chem. J. 1903, **29**, 505.
[6] Minnesota Agr. Exp. Sta. 1903, Bul. **85**.
[7] J. Ind. Eng. Chem. 1912, **4**, 274.
[8] Cereal Chem. 1929, **6**, 515.
[9] Ibid. 1931, **8**, 29.

Relation of Acidity to Ash, Phosphorus, and Amino Compounds (Swanson)

	Patent flour (70 per cent)	Clear flour (27 to 27.5 per cent)	Low-grade flour (2.3 to 3 per cent)	Wheat
	%	%	%	%
Ash	0.52	0.83	1.08	1.93
Acidity:				
Water-soluble at 25°	0.074	0.170	0.215	0.156
Water-soluble at 40°	0.130	0.245	0.339	0.478
Phosphorus:				
Water-soluble at 25°	0.021	0.071	0.097	0.066
Water-soluble at 40°	0.028	0.098	0.152	0.218
Total	0.110	0.187	0.269	0.482
Amino compounds:				
Calculated as proteins	0.162	0.270	0.396	0.530

to furnish sharp distinctions between the higher and lower grades. Bailey and Peterson,[1] however, have demonstrated that by the determination of the *p*H of 1 : 5 extracts, prepared by digestion at 25° C. for 1 hour, before and after adding 20 cc. of 0.02 normal sodium hydroxide per 100 cc., differences are obtained, representing the buffer action, which closely parallel the percentages of ash.

In order to show the relation of these differences to ash and electrical conductivity, the following table has been compiled from results obtained by Bailey and Peterson,[2] who studied the hydrogen ion concentration in its different aspects, and Bailey and Collatz,[3] who first proposed utilizing the electrical resistance as a means of distinction. The products were the same in both cases. The extracts used for the determinations of hydrogen ion concentration and electrical conductivity were respectively in the proportion of 1 : 5 and 1 : 10; the time of digestion respectively 1 hour and 30 minutes, the temperature of digestion being 25° C. in both cases.

After three years' experience in the determination of hydrogen ion concentration of wheat, Weaver [4] gives 6.21 to 6.84 as the range for all samples examined and 6.43 to 6.77 for wheat actually received at the mill he represented.

[1] J. Ind. Eng. Chem. 1921, **13**, 916.
[2] Loc. cit.
[3] Ibid. 1921, **13**, 319.
[4] Cereal Chem. 1925, **2**, 209.

ASH, HYDROGEN ION CONCENTRATION, BUFFER ACTION, AND ELECTRICAL CONDUCTIVITY OF MILL PRODUCTS (BAILEY, ET AL.)

	Ash	*p*H extract	*p*H ext. + NaOH*	*p*H difference	$K_{30} \times 10^{-4}$ extract
	%				
1st middlings	0.44	6.07	9.28	3.21	5.40
2nd middlings	0.45	6.10	8.72	2.62	5.55
3rd middlings	0.55	6.22	8.59	2.37	6.34
2nd break	0.58	6.25	8.52	2.27	6.65
5th middlings	0.61	6.31	8.38	2.07	6.78
3rd break	0.67	6.22	7.89	1.67	7.69
4th middlings	1.17	6.42	7.29	0.87	10.24
1st break	1.34	6.34	7.17	0.83	10.56
4th break †	1.62 †	6.44	7.02	0.58	11.97

* 20 cc. 0.02 N sodium hydroxide.

† These figures are by Bailey and Collatz. Bailey and Peterson give "2nd break" and ash "2.38," which appear to be misprints since the 2nd break appears twice.

Bailey and Johnson[1] report that bleaching patent and clear flour, containing 0.43 and 0.84 per cent of ash respectively, with 20 cc. of chlorine per 100 grams, produced a change in hydrogen ion concentration of 0.34 and 0.17 respectively. The smaller change for the clear flour was due to higher buffer action.

Weaver [2] found that bleaching of flour by the Alsop process raised the hydrogen ion concentration slightly (0.04 to 0.20), by the chlorine process, considerably (0.06 to 0.57).

In the experience of Dixon [3] the quality of commercial flour as indicated by baking tests cannot be predicted from the hydrogen ion concentration or buffer effect value of the wheat or of the laboratory-milled flours, as these values are governed by the special treatment in milling.

Johnson and Green[4] found that the hydrogen ion concentration of water extracts of freshly milled flour and of the same flour after storage and extraction with ether were the same, thus suggesting that acids soluble in ether are the sole cause of the increase of acidity and hydrogen ion concentration during storage.

Electrical Conductivity.—Bailey and Collatz [5] have demonstrated

[1] J. Ass. Off. Agr. Chem. 1922, **6**, 63.

[2] Loc. cit.

[3] N. Zealand J. Sci. Tech. 1930, **12**, 146.

[4] Cereal Chem. 1931, **8**, 134.

[5] Loc. cit.

that wheat milling products may be differentiated by determination of the electrical conductivity ($K_{30} \times 10^{-4}$) of a 1 : 10 water extract obtained by digestion at 25° C. for 30 minutes. They point out that time and temperature of digestion appreciably influence the results, paralleling those obtained by them[1] in the study of the action of phytase. This suggests that the conductivity is due largely to inorganic salts of phosphoric acid resulting from the hydrolysis of phytin. A comparison of their results with those for ash and hydrogen ion concentration is tabulated above.

Bailey and Johnson[2] found that patent and clear flour, bleached with chlorine to the extent of 20 cc. per 100 grams, showed an increase of the electrical conductivity of 0.48 and 0.73 respectively.

Enzymes.—*Protease* occurs in wheat as well as in other cereals. Giesen[3] found in the kernel 0.65 and in the bran 1.1 per cent, calculated in terms of trypsin, the optimum temperature being 30 to 40° C. Cairus and Bailey[4] have studied the methods of measuring the proteolysis of flour suspensions.

Tyrosinase.—The darkening of whole wheat flour was shown by Mège-Mouriès and Boutroux to be due to an oxidase. Bertrand and Muttermilch[5] proved that the enzyme is tyrosinase, not laccase. A protease (glutenase) acts in a preliminary stage forming tyrosine.

Amylase, which appears in wheat as in all cereals during sprouting, also was found by Eisenberg[6] in small amount during the resting stage. Naylor, Spencer, and House[7] state that the amylase of wheat malt agrees in composition and activity with that of barley malt as found by Osborne and by Sherman. Karmarkar and Patwardhan[8] state that it is even more active than barley amylase. Its optimum temperature is between 49 and 58°; its optimum *p*H is 4.6. Heating at 160° for one hour destroys its activity.

Maltase, according to Wierzchowski,[9] is present in small amount.

Oxalase, an enzyme oxidizing oxalic acid with formation of carbon dioxide, has been found by Zalesskii and Kukharkova[10] in wheat.

[1] J. Ind. Eng. Chem. 1921, **13**, 317.
[2] Loc. cit.
[3] Inaug. Dis. Bern. 1909.
[4] Cereal Chem. 1928, **5**, 79.
[5] Compt. rend. 1907, **144**, 1285, 1444.
[6] Flora 1907, **97**, 347.
[7] J. Am. Chem. Soc. 1925, **47**, 3037.
[8] J. Indian Inst. Sci. 1930, **13A**, 159.
[9] Biochem. Z. 1913, **57**, 125.
[10] Ukrainskii Khem. Zhurn. 1928, **3**, Pt. sci. 139.

Peroxidase.—Coupin[1] obtained a blue color by the benzidine test indicative of peroxidase.

Influence of Ripening.—According to Bach, Oparin, and Vener,[2] catalase and peroxidase decrease slightly during ripening and amylase and protease disappear. All these increase greatly during germination.

Influence of Climate.—Lishkevich and Prizemina [3] state that northern-grown grain not only differs in its proximate composition from southern-grown but also contains more protease, amylase, and catalase owing to failure to reach full maturity.

Influence of Storage.—Wheat that has lost its vitality is stated by Oparin and Pospelowa [4] to still contain amylase, catalase, and peroxidase.

Mineral Constituents.—Snyder [5] determined the ash constituents of 12 samples of wheat, grown in different parts of Minnesota, from the same seed, showing variation in weight from 65 to 55 lb. per bushel. The composition of the heaviest and the lightest, also, calculated to the pure ash, the average of Snyder's 12 analyses and of 48 analyses reported by Lawes and Gilbert[6] appear in the following table:

Ash Analyses of Heavy Weight, Light Weight, and Average Wheat

	Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl	CO_2
	%	%	%	%	%	%	%	%	%	%	%
Snyder:											
65 lb. per bu. . .	2.00	32.46	0.67	2.55	12.39	0.27	50.76	0.36	0.37	0.11	1.30
55 lb. per bu. . .	2.09	28.77	0.88	4.52	14.48	0.86	43.07	0.12	1.92	0.42	3.02
Aver. of 12 anal.	**2.03**	**31.1**	**0.7**	**3 6**	**13.6**	**0.6**	**49.4**	**0.1**	**0.8**	**0.1**	
L. and G.:											
Aver. of 48 anal.	....	**32.7**	**0.6**	**3.0**	**10.7**	**0.9**	**49.6**	**1.4**	**1.0**	**0.1**	

In the studies of the influence of fertilizers on composition described above, Headden made 36 complete ash analyses representing the wheat of the unfertilized and fertilized plots during the years 1913, 1914, and 1915. The following table below gives the mineral constituents of the wheat from the unfertilized plots in percentages of the air-dry kernels.

Analyses by Sullivan and Near [7] of 20 samples of wheat, indicate (with one exception, Kansas A) that the magnesium content bears a

[1] Compt. rend. 1925, **180**, 685.
[2] Trans. Karpov Inst. Chem. 1926, No. 5, 62.
[3] Biochem. Z. 1929, **212**, 280.
[4] Ibid. 1927, **189**, 18.
[5] Minnesota Agr. Exp. Sta. 1893, Bul. **29**, 149.
[6] Johnson: How Crops Grow. New York, 1893, p. 164.
[7] J. Am. Chem. Soc. 1927, **49**, 467.

MINERAL CONSTITUENTS OF WHEAT GROWN THREE SUCCESSIVE YEARS WITHOUT FERTILIZER (HEADDEN)

	K	Na	Ca	Mg	Fe	Mn	P	S	Cl	SiO_2
	%	%	%	%	%	%	%	%	%	%
Defiance:										
1913...	0.391	0.037	0.037	0.141	0.005	+	0.416	0.116	0.060	0.030
1914...	0.437	0.014	0.041	0.147	0.003	0.004	0.426	0.137	0.121	0.018
1915...	0.465	0.022	0.054	0.162	0.005	0.004	0.383	0.100	0.085	0.019
Red Fife:										
1913...	0.444	0.010	0.038	0.150	0.006	+	0.461	0.113	0.135	0.017
1914...	0.437	0.016	0.030	0.156	0.005	0.005	0.412	0.119	0.114	0.015
1915...	0.447	0.034	0.046	0.141	0.004	0.004	0.390	0.087	0.063	0.014
Kubanka:										
1913...	0.454	0.010	0.031	0.137	0.005	+	0.423	0.093	0.130	0.030
1914...	0.442	0.041	0.033	0.140	0.004	0.005	0.385	0.123	0.142	0.010
1915...	0.427	0.029	0.035	0.135	0.007	0.004	0.391	0.106	0.053	0.022

direct ratio to strength as determined by protein content and gluten quality, as shown below:

COMPOSITION OF WHEAT SHOWING RELATION OF MAGNESIA TO PROTEIN AND GLUTEN (SULLIVAN AND NEAR)

(Results calculated to dry basis)

	Marquis (Montana)	Marquis (N. Dakota)	Turkey Red (S. Dakota)	Kansas A (Kansas)	Kansas B (Kansas)	Sonora (California)
	%	%	%	%	%	%
Protein (N×5.7).....	19.65	15.09	13.64	16.02	12.24	10.43
Gluten.....	16.28	14.97	12.00	13.41	10.95	9.10
Gluten quality.....	very good	good	poor	good	poor	very poor
Ash.....	1.90	2.01	2.08	2.21	2.15	1.95
Composition of ash:						
K_2O.....	33.35	28.48	28.75	29.50	28.80	30.89
CaO.....	3.14	2.83	3.38	3.75	3.00	3.26
MgO.....	16.30	15.69	14.25	13.50	14.78	11.47
P_2O_5.....	46.05	50.67	50.74	51.06	50.53	51.45
SiO_2 and C.....	1.06	1.67	1.10	1.63	2.10	1.37

Mineral Constituents of Wheat Products.—Analyses of the ash of Arkansas Winter wheat and of the various products and by-products of the same wheat made from it have been carried out by Teller,[1] as shown in the table below:

[1] Arkansas Agr. Exp. Sta. 1896, Bul. **42**, 70.

Ash Analysis of Winter Wheat and Its Milling Products (Teller)

	Ash	K_2O	CaO	MgO	Fe_2O_3	Al_2O_3	ZnO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
Patent flour....	0.31	38.50	5.59	4.39	0.47	0.41	....	48.05	0.16	2.33	
Straight flour..	0.40	36.31	5.65	6.44	0.26	0.15	0.04	49.32	0.52	1.28	
Low-grade.....	0.70	32.27	4.51	9.33	0.25	0.12	....	53.10	....	0.50	
Dust room.....	2.50	30.85	3.53	12.90	0.30	0.04	0.46	49.94	0.58	1.34	
Ship stuff.....	3.08	28.03	2.80	13.27	0.37	0.18	0.36	54.62	....	0.49	
Bran.....	5.25	28.19	2.50	14.76	0.27	0.07	0.27	52.81	0.10	0.97	0.01
Wheat.....	1.62	29.70	3.10	13.23	0.27	0.11	0.24	52.14	0.22	1.04	0.01

Teller's analyses furnished data for calculation of the percentages of the different mineral ingredients in the products themselves given in the original publication. They also show the presence of zinc in the wheat of that region, a metal which more recently has come to be regarded as a normal constituent of wheat of many other regions. Alumina was unmistakably present in the wheat, although the same author failed to find it in a sample of Michigan wheat. Its introduction into the flour from burr stones was precluded by the roller process employed in milling. Teller notes the absence of soda, which most careful analysts find in small amount. In any event, the percentage of soda in wheat is small. The determination of this element requires special precautions which, unobserved, are reflected in many high results which have crept into the literature.

Sullivan and Near [1] have determined the ash constituents in Marquis wheat, a typical dark, northern, hard, Spring variety, grown in North Dakota, and the mill products of this wheat. Their analyses included, in addition to the usual elements determined, manganese, copper, zinc, and aluminum. They also reported figures for protein, dry gluten, ether extract, and lipoid. In addition they note the presence of minute amounts of boron, fluorine, arsenic, and iodine which, together with the other less commonly found elements, occur in the smallest amount in the highest grades of flour. Their figures are given in the table on the following page.

Mineral Constituents in Mill Streams.—The streams obtained in the milling process represent a greater number of separations than the finished products, as several streams may be combined in making each grade of flour and the by-products are often various mixtures. Richardson,[2] in connection with his proximate analyses of the different streams in two mills in the early days of roller milling, also determined the phosphoric acid but no other ash constituents.

[1] J. Ind. Eng. Chem. 1927, **19**, 498.

[2] U. S. Dept. Agr., Div. Chem. 1884, Bul. **4**, 38.

COMPOSITION OF HARD SPRING WHEAT AND ITS MILLING PRODUCTS (SULLIVAN AND NEAR)

(Results calculated to dry basis)

	Patent flour	Clear flour	Low-grade flour	Total mill-run middlings	Bran	Germ*	Wheat
	%	%	%	%	%	%	%
Yield	58.00	12.00	2.60	14.41	12.99		
Protein	14.13	17.76	18.47	18.55	17.76	29.20	15.09
Organic gluten	14.49	18.16	.....	.....	.....	.....	14.97
Ether extract	1.41	2.35	3.75	6.57	6.40	11.94	2.53
Lipoid	1.62	2.64	4.23	6.14	6.67	11.25	3.40
Fiber	.....	.....	.....	7.00	8.27	2.90	
Ash	0.482	0.804	1.462	4.762	6.748	5.041	2.05
Composition of ash:							
K_2O	27.82	25.22	25.30	28.50	26.04	26.49	28.48
CaO	5.22	3.94	3.60	3.35	2.40	1.92	2.83
MgO	10.60	12.87	15.02	15.83	17.60	12.50	15.69
Fe_2O_3	0.229	0.200	0.214	0.243	0.200	0.192	0.214
Al_2O_3	0.025	0.047	0.094	0.032	0.075	0.094	0.030
Mn_2O_3	0.045	0.083	0.115	0.144	0.191	0.240	0.144
CuO	0.044	0.029	0.036	0.033	0.026	0.024	0.036
ZnO	1.037	0.747	1.095	0.834	1.037	1.037	0.622
P_2O_5	55.20	54.37	54.95	50.20	51.57	56.90	50.67
SiO_2 and C	0.60	1.16	0.66	1.17	0.43	0.80	1.67

* Taken from spout before stream reached the bran and middlings with which it is mixed. The amount of this germ was less than 1 per cent.

A study of the amount of iron, calcium, magnesium, and phosphorus in Marquis wheat and the mill streams obtained therefrom has been carried out by Harding and Dysterheft.[1] For ready comparison with preceding tables, the figures for iron, calcium, and manganese, given in the original publication, have been recalculated and incorporated in the table on the following page.

In their summary, Harding and Dysterheft note that the iron-ash ratio and iron-magnesium ratio are remarkably constant in all the streams, whereas the iron-calcium ratio shows no such constancy and the calcium-magnesium ratio increases in the break streams and in the middlings streams (excepting the third) with the number of the streams,

[1] Cereal Chem. 1927, 4, 47.

Composition of Ash of Hard Spring Wheat and Mill Streams (Harding and Dysterheft)

(Results calculated to dry basis)

	Break Streams				Middlings				Flour		Bran	Wheat
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	Straight	Clear		
	%	%	%	%	%	%	%	%	%	%	%	%
Protein *. .	14.73	13.70	16.95	18.80	11.73	11.47	11.71	12.10	12.54	14.52	15.16	14.17
Ash.	0.68	0.67	0.84	1.34	0.42	0.40	0.42	0.45	0.51	0.81	4.87	1.76
In ash:												
CaO. .	3.77	2.53	2.94	2.60	5.52	3.53	5.52	3.09	3.12	4.25	2.77	2.52
MgO. .	13.23	12.24	13.56	14.29	8.80	9.16	9.68	10.21	10.30	12.55	15.34	14.52
Fe_2O_3.	0.17	0.15	0.17	0.16	0.12	0.13	0.14	0.15	0.14	0.16	0.16	0.15
P_2O_5. .	56.33	54.16	53.91	54.91	49.85	56.08	60.00	58.78	59.03	55.69	53.36	49.92

* N×5.70.

following the general rule which Bailey has established in proceeding from the lower to the higher grades of flour.

Relation of Mineral Constituents to Milling Grade.—All the three foregoing tables illustrate clearly that in passing from the highest milled product (patent flour) to the lowest (bran) the percentage of magnesium in the ash and the ratio of magnesium to ash increase whereas the percentage of lime decreases. Further calculation to percentages of the materials themselves would show an increase of all the ash constituents, including lime and the rarer elements, as is true of the protein, fat, lipoid, and total ash.

Minor Mineral Constituents. *Iron.*—Wheat 45 to 52, wheat flour 13 to 17 mg. per kilo, air-dry basis (Sherman).[1] Wheat, 10 varieties, 31 to 51, aver. 39 mg. per kilo, dry basis (McHargue).[2] Wheat flour 24, wheat bran 210, wheat germ 210 mg. per kilo, dry basis (McHargue).[3] (See also ash analyses above.)

Aluminum.—According to Teller, as stated above, it may or may not be present in wheat. (See also ash analyses above.)

Manganese.—Wheat 28 mg. per kilo, dry basis (Wester).[4] Wheat, 10 varieties, 36 to 73, aver. 47 mg. per kilo, dry basis (McHargue).[2] Wheat flour 10, wheat bran 125, wheat germ 150 mg. per kilo, dry basis (McHargue).[3] Wheat 11.5 and 13.8 mg. per kilo, air-dry basis (Quartaroli).[5] Wheat, 5 varieties each: hard Winter 34 to 68, soft Winter 86 to 86, hard red Spring 34 to 60, white Spring 68 to 86 mg. per kilo, dry basis (Davidson).[6] (See also ash analyses above.)

[1] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. 185.
[2] J. Agr. Res. 1923, 23, 395.
[3] Ibid. 1925, 30, 193.
[4] Biochem. Z. 1921, 118, 158.
[5] Ann. chim. appl. 1928, 18, 47.
[6] Cereal Chem. 1929, 6, 128.

Copper.—Wheat 4.5 mg. per kilo, dry basis (Maquenne and Demoussy).[1] Wheat 7.2 mg. per kilo, air-dry basis (Guerithault).[2] Wheat flour trace, wheat bran 16, wheat germ 46 mg. per kilo, dry basis (McHargue).[3] Wheat 3.57 and 5.7 mg. per kilo, dry basis (Quartaroli).[4] (See also ash analyses above.)

Zinc.—Wheat flour 22, wheat bran 75, wheat germ 160 mg. per kilo, dry basis (McHargue).[5] Wheat, 4 varieties, 26 to 85, wheat bran 139 mg. per kilo, air-dry basis (Birckner).[6] Whole wheat 18.7, wheat bran 38 mg. per kilo, dry basis (Bertrand and Benzon).[7] (See also ash analyses above.)

Arsenic.—Present (Sullivan and Near).[8]

Iodine.—Wheat flour and wheat gluten less than 1.5, wheat germ less than 2.5 mg. per kilo (Bohn).[9] None (Winterstein).[10]

Boron and *Fluorine.*—Present (Sullivan and Near).[8]

Baking Strength of Flour.—This topic, of first importance in bread-making, has been the subject of much discussion and many investigations. That differences in baking qualities are not due to differences in constitution of either the gliadin or the glutenin is indicated by the work of Wood,[11] Blish,[12] and Cross and Swain,[13] who have obtained the hydrolyzation products of these proteins, and of Blish and Pinckney,[14] who have studied their racemization in alkaline solution and their specific rotation. The latter authors failed to confirm the results of Woodman,[15] who concluded that glutenins from different flours are not the same in the linkage of the amino acids. Blish, in a later paper,[16] refutes Halton's conclusion[17] that each flour contains two glutenin "fractions" of different chemical configuration.

Gortner and Doherty,[18] Sharp and Gortner,[19] and Upson and Calvin,[20] as well as certain German investigators, believe that the colloidal condi-

[1] Compt. rend. 1920, **170**, 87.
[2] Ibid. 1920, **171**, 196.
[3] Loc. cit.
[4] Loc. cit.
[5] J. Am. Soc. Agron. 1925, **17**, 368.
[6] J. Biol. Chem. 1919, **38**, 191.
[7] Bul. soc. hyg. aliment. 1928, **16**, 457.
[8] Loc. cit.
[9] J. Biol. Chem. 1917, **28**, 375.
[10] Z. physiol. Chem. 1918, **104**, 54.
[11] J. Agr. Sci. 1907, **2**, 139.
[12] J. Ind. Eng. Chem. 1916, **8**, 138.
[13] Ibid. 1924, **16**, 49.
[14] Cereal Chem. 1924, **1**, 309.
[15] J. Agr. Sci. 1922, **12**, 231.
[16] Cereal Chem. 1925, **2**, 127.
[17] J. Agr. Sci. 1924, **14**, 587.
[18] J. Agr. Res. 1918, **13**, 389.
[19] Minnesota Agr. Exp. Sta. 1923, Tech. Bul. **19**.
[20] Nebraska Agr. Exp. Sta. 1916, Res. Bul. **8**.

tion of the gluten and its hydration properties are the dominating characters influencing strength.

Coleman, Dixon, and Fellows,[1] after a comparison of tests for quality of gluten in wheat or flour, decided that the determination of crude protein ranks first and of washed-gluten ranks second in value, the latter yielding remarkably good results in the hands of a single operator. Of the recently devised viscosity methods, the "single concentration test" was the only one that gave any satisfaction, being decidedly better than tests of kernel texture or water-absorbing power.

Further details on this and other matters pertaining to the bread-making qualities of flour, which are beyond the province of this work, are given in C. H. Bailey's "Chemistry of Wheat"[2] and the papers named above.

CHEMICAL COMPOSITION OF BREAD AND ALLIED PRODUCTS. Wheat Bread.—The variations in the composition of flour, due to kind of wheat and milling grade, are further accentuated when the flour is made into bread or crackers, owing to the wider difference in the water content and the addition of varying amounts of shortening, milk, sugar, and salt. Bread made with little or none of these four constituents, so far as the usual analysis is concerned, differs little from the flour except as regards the water content, the amount of yeast being inconsiderable. Shortening increases only the fat. Whole milk increases to some extent both fat and protein.

Tables of analyses show such variations as to leave one in doubt as to which conforms most nearly to a given product. Indeed, except for showing within certain limits the water content, they furnish little information beyond what may be reached by calculation, if one knows the kind and amount of the constituents.

Only a very general idea may be gained from the following table, which groups under three heads the common forms of bread and rolls, the latter including various kinds of moist biscuit raised with yeast or baking powder.

The most striking difference brought out in the table is the lower water content of the rolls due to their smaller size and relatively greater amount of crust. Graham or true whole wheat bread contains less rather than more protein than white bread. Its somewhat greater fiber content is not so marked as one might believe from its coarser nature.

Crackers (known in England as biscuit) are characterized in general by their low water and high fat content. In their simplest form, where the amount of added fat and salt is small, their composition is essen-

[1] J. Agr. Res. 1927, **34**, 241.

[2] New York, 1925.

Composition of White and Graham Bread and Rolls (Atwater and Bryant)

	Samples	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
White bread: *	103						
Min.		25.8	7.0	0.0	42.0	0.3	0.6
Max.		49.1	13.9	3.7	61.5	0.9	3.0
Aver.		**35.6**	**9.3**	**1.2**	**52.7**	**0.5†**	**1.2**
Rolls:	20						
Min.		18.4	6.3	0.4	49.0	0.3	0.1
Max.		36.7	11.9	13.7	64.7	2.1	1.6
Aver.		**29.2**	**8.9**	**4.1**	**56.7**	**0.6†**	**1.1**
Graham bread:	27‡						
Min.		27.8	6.8	0.4	38.6	0.6	0.7
Max.		42.4	10.9	3.8	59.1	1.8	3.0
Aver.		**35.7**	**8.9**	**1.8**	**52.1**	**1.1†**	**1.5**

* Four samples with average of sugar 2.3, dextrin 4.2, and starch 48.2 per cent.
† Fiber determinations only in part of the samples.
‡ Two samples with average of sugar 3.2, dextrin 3.1, and starch 40.8 per cent.

tially that of flour with a trifle higher fat and ash content. The variation even in crackers of the same name is far greater than differences in the flour from which they are made.

An extensive investigation has been made by Johnson and C. H. Bailey [1] of the flour used in the cracker industry, also of the fermentation of the dough and the reaction of the finished product as measured by the hydrogen ion concentration.

The flour was for the most part from soft wheat and had an average ash content of 0.49 per cent and an average protein content of 9.28 per cent. Of the 121 samples examined, 85 contained between 8 and 10 per cent of protein, 10 between 7 and 8 per cent, and 1 less than 7 (6.33) per cent. Only 25 contained over 10 per cent of protein. The acidity of the dough developed during fermentation was at its maximum when the *p*H reached 4.0 ± 0.2. It was found desirable to add to this acid dough sufficient sodium bicarbonate to more than neutral reaction, a hydrogen ion concentration corresponding to *p*H 7.00 to 7.10 being the optimum.

On baking, the alkalinity increased, owing to conversion of the bicarbonate to the carbonate. An excess of free alkali promoted caramelization. Reducing sugar increased during the first 6 hours of fer-

[1] Cereal Chem. 1924, **1**, 327.

mentation, then decreased as the fermentation enzymes began to function more rapidly.

In 60 samples of crackers made by different American manufacturers the reaction varied greatly, the most alkaline having an alkalinity represented by *p*H 8.81; the most acid, an acidity represented by *p*H 5.71, the average of all the samples being *p*H 7.84.

After storage for 7 weeks an increase in acidity amounting to a decrease *p*H of 0.3 ± was noted which did not appear to be correlated with rancidity.

The kind of shortening in the crackers examined was usually lard, but in a few cases was oleo oil, corn oil, or hydrogenated cottonseed oil; the amount of shortening varied up to 24 lb. per barrel of flour, equivalent to about 11 per cent.

Only a few types, all, with the exception of Graham crackers, unsweetened, are included in the following table:

Composition of Crackers (Biscuit)

(Atwater and Bryant)

	Samples	Water	Protein (N × 6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Soda crackers:	5						
Min.		3.7	8.8	7.7	70.5	.....	1.8
Max.		8.4	10.7	10.0	75.4	.....	2.6
Aver.		**5.9**	**9.8**	**9.1**	**73.1**	**0.3***	**2.1**
Oyster crackers:	7						
Min.		3.8	9.1	4.8	69.1	.....	0.9
Max.		6.5	17.3	13.0	77.5	.....	5.9
Aver.		**4.8**	**11.3**	**10.5**	**70.5**	**0.2***	**2.9**
Pilot bread:	3						
Min.		7.9	10.4	0.5	70.3	0.3	0.9
Max.		9.9	12.4	10.2	78.0	0.3	1.1
Aver.		**8.7**	**11.1**	**5.0**	**74.2**	**0.3***	**1.0**
Pretzels:	2						
Min.		8.1	9.1	3.9	71.1	0.4	3.2
Max.		11.0	10.3	3.9	74.5	0.5	4.9
Aver.		**9.6**	**9.7**	**3.9**	**72.8**	**0.5***	**4.0**
Graham crackers:	4						
Min.		3.1	7.4	1.1	69.7	0.6	1.2
Max.		8.4	14.4	13.6	77.2	2.4	1.9
Aver.		**5.4**	**10.0**	**9.4**	**73.8**	**1.5***	**1.4**

* Fiber determinations only in part of the samples.

Cake and Cookies.—Under this head are included sweetened bakery products. As regards moisture, cake bears the same relation to cookies as bread to crackers. In addition to sweetening and flavoring they usually contain added fat (butter, lard, or vegetable shortening) or eggs, or both. Milk, skimmed milk, or dried skimmed milk may be substituted for all or part of the eggs. Certain varieties, such as coffee cake and raised dougnhuts, are leavened with yeast, but in the United States most kinds of cake are made with baking powder or its equivalent in baking chemicals. Sponge cake of the highest type is made from flour, sugar, and eggs alone without the addition of either yeast or baking powder, the eggs serving to aerate the loaf.

Compared with bread, cake in general contains less moisture, much more fat, more nitrogen-free extract (due to sugar) but less starch and less protein. These statements apply whether or not the analysis is calculated to the dry basis. They are readily understood when one considers that sweetening and shortening each add one non-nitrogenous nutrient, respectively sugar and fat, thus of necessity depressing the protein and starch. Eggs increase to some extent the protein as well as the fat, but they are not commonly present in sufficient amount to overcome the opposite influence of the sweetening and shortening.

Because of the endless recipes for cake, even of the same name, tables of composition are of limited value. By varying the amount of frosting alone the composition may be greatly changed. Only by actual analysis or careful calculation based on the amount and composition of the ingredients can the true amount of the constituents be determined.

On the following page are figures, taken from Atwater and Bryant's Compilation, which compared with analyses of bread and crackers serve to bring out the points mentioned.

Alimentary Pastes.—*Macaroni*, *Spaghetti*, *Vermicelli*, and *Water Noodles* are prepared from the dough of coarsely ground flour (semolina) made from durum wheat or some other variety rich in protein. They correspond closely in composition with the flour from which they are made and differ from one another in the characteristic forms obtained by forcing the dough through a perforated plate or cutting it into strips. A summary of analyses by Winton and Ogden [1] is given below.

Egg Noodles are made with eggs or egg yolks, which increase the constituents, other than nitrogen-free extract, beyond the amounts present in the flour. Of particular interest is the increase in lecithin as measured by the percentage of lecithin-phosphoric acid.

[1] Connecticut Agr. Exp. Sta. Rep. 1901, p. 198.

Composition of Cake and Cookies (Atwater and Bryant)

	Samples	Water	Protein (N × 6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Cake:	27						
Min.		6.3	4.6	2.5	52.4	0.1	0.6
Max.		34.4	9.0	15.6	78.8	0.9	4.3
Aver.		**19.9**	**6.3**	**9.0**	**63.3**	**0.4***	**1.5**
Doughnuts:	9						
Min.		11.0	5.1	16.4	45.8	0.6	0.3
Max.		25.8	7.6	25.7	63.2	0.8	1.9
Aver.		**18.3**	**6.7**	**21.0**	**53.1**	**0.7***	**0.9**
Sugar cookies:	9						
Min.		4.3	4.5	4.8	69.1	0.3	0.6
Max.		13.3	8.0	16.7	84.4	2.9	3.4
Aver.		**8.3**	**7.0**	**10.2**	**73.2**	**1.1***	**1.3**
Ginger snaps:	7						
Min.		4.3	5.8	2.3	71.9	0.4	1.8
Max.		9.7	7.3	15.4	80.8	0.9	3.7
Aver.		**6.3**	**6.5**	**8.6**	**76.0**	**0.7***	**2.6**

* Fiber determinations only in part of the samples.

Composition of Alimentary Pastes (Winton and Ogden)

	Samples	Water	Protein (N×6.25)	Fat	N-f. ext. and fiber	Ash
	37	%	%	%	%	%
Macaroni:						
Min.		10.3	11.9	0.2	64.8	0.4
Max.		14.3	20.7	1.1	75.6	1.0
Aver.		**12.7**	**14.0**	**0.4**	**72.2**	**0.7**
Spaghetti:	8					
Min.		12.7	11.9	0.2	72.6	0.5
Max.		13.4	13.4	0.6	73.9	0.7
Aver.		**13.0**	**12.7**	**0.4**	**73.3**	**0.6**
Vermicelli:	10					
Min.		11.5	12.1	0.3	71.5	0.5
Max.		12.7	15.3	0.6	74.3	1.0
Aver.		**12.3**	**13.5**	**0.4**	**73.1**	**0.7**
Noodles (water):	22					
Min.		12.0	12.2	0.2	70.8	0.5
Max.		13.8	15.4	0.7	73.8	1.2
Aver.		**12.9**	**13.1**	**0.4**	**72.9**	**0.7**

Juckenack [1] and Juckenack and Pasternack[2] adopted the following average percentages as present in flour and water noodles: lecithin-phosphoric acid 0.0225, total phosphoric acid 0.23, fat 0.66, protein 12.00 and ash 0.46. They calculated the increase for each added egg and egg yolk of average weight and composition per 500 grams of flour. These constituents in noodles containing 1 to 3 eggs per 500 grams range as follows: lecithin-phosphoric acid 0.0513 to 0.1044, total phosphoric acid 0.27 to 0.35, fat 1.56 to 3.24, protein 12.99 to 14.81, and ash 0.57 to 0.76 per cent.

The figures for noodles made with egg yolk alone differ little from the foregoing except in the protein and ash, which range respectively as follows: protein 12.37 to 13.07, and ash 0.49 to 0.54 per cent.

These figures do not take into account the variation in the composition of flour and eggs and of the weight of each egg. As they were designed merely to aid in the valuation of commercial egg noodles in conformity to legal regulations, they are based on figures which give the manufacturer the benefit of the doubt. In hard wheat flour, Juckenack and Pasternack found as high as 0.0435 per cent of lecithin-phosphoric acid. A more accurate idea of the composition of the noodles may be gained if an actual analysis of the flour is taken as the starting point, accepting Juckenack's increments per egg of the different constituents.

DWARF WHEAT

Triticum sativum Lam. var. *compactum* (Host.) Hackel = *T. compactum* Host.

Ger. Zwergweizen.

Hedgehog or dwarf wheat is a prehistoric form grown by the lake dwellers and still cultivated in Switzerland and regions adjoining on the north and east.

It corresponds to common wheat in structure.

ENGLISH WHEAT

Triticum sativum Lam. var. *turgidum* (L.) Hackel = *T. turgidum* L.

Fr. Froment renflé. Sp. Trigo rendondillo. Ger. Englischer Weizen.

Although known as English wheat, this variety is seldom grown outside of the Mediterranean region. It yields a gray flour with low gluten content not well suited for bread.

[1] Z. Unters. Nahr.-Genussm. 1900, **3**, 13.

[2] Ibid. 1904, **8**, 94.

MACROSCOPIC STRUCTURE.—The kernels are short, broad, and blunt at the apex and are not compressed.

MICROSCOPIC STRUCTURE.—The microscopic characters have been found to be practically the same as those of common wheat except that certain sports, occurring among the usual form, produce kernels of a madder-red color due to bluish red contents of the *aleurone cells*.

CHIEF STRUCTURAL CHARACTERS.—Kernels short. Like wheat in structure.

DURUM WHEAT

Triticum sativum Lam. var. *durum* (Desf.) Hackel = *T. durum* Desf.

Fr. Blé dur. Sp. Trigo duro. It. Grano duro. Ger. Hartweizen.

Macaroni or durum wheat, believed to be of recent origin, is grown in countries about the Mediterranean, Black, and Caspian Seas and in parts of North and South America. Flour from this variety is best suited for alimentary pastes.

MACROSCOPIC STRUCTURE.—The *kernel* is characterized by the hard, horny endosperm developed commonly to the complete exclusion of floury endosperm, also by the angular form and the large size of the kernel, the length reaching 10 mm. or more and the breadth 4 mm.

Certain Abyssinian varieties, according to Körnicke and Werner,[1] have brown or purple-violet kernels, the color being due to the walls of the epicarp and hypoderm, and the uniform (not granular) contents of the cross cells.

MICROSCOPIC STRUCTURE.—In general histological characters, macaroni wheat is like common wheat. The microscopic examination of alimentary pastes is carried out, after grinding to a powder, as described for flour under Wheat, remembering that since the gluten has been formed in their preparation the Bamihl test is not applicable.

Artificial colors such as the tropæolins give color reactions in the acid treatment preliminary to the examination of the cellular tissues. Eggs are a constituent of true noodles.

CHIEF STRUCTURAL CHARACTERS.—Kernel large, angular, horny. Like wheat in microscopic structure.

POLISH WHEAT

Triticum polonicum L.

Fr. Froment de Pologne. Sp. Trigo polaco. Ger. Polnischer Weizen.

This is the only naked wheat which systematists seem disposed to leave with its Linnean name notwithstanding De Candolle's statement

[1] Handbuch des Getreidebaues. Berlin, 1885, pp. 26–28.

that it has not been found wild and is doubtless a form obtained by cultivation. Although known as Polish wheat, Poland does not appear to be its home; De Candolle places it in Eastern Europe, Gilg in Spain.

MACROSCOPIC STRUCTURE.—The *kernels* are even harder than those of macaroni wheat, and larger, reaching 12 mm. in length. In shape they are more like rye, hence the name "giant rye."

MICROSCOPIC STRUCTURE.—No histological differences from common wheat have come to our knowledge.

SPELT

Triticum sativum Lam. var. *Spelta* (L.) Hackel = *T. Spelta* L.

Fr. Épeautre. Sp. Escanda. It. Spelda. Ger. Spelt.

Spelt is the most important of the chaffy wheats, a group in which, like most barleys, the fruit is not separated from the floral envelopes on threshing.

Authorities are not agreed as to the origin of this variety. De Candolle finds no conclusive evidence of its ancient cultivation in the Orient or Mediterranean countries but states that history and especially philology point to an origin in eastern temperate Europe and the neighboring countries of Asia and inclines to the view that it was "derived by cultivation from common wheat or an intermediate form at some not very early prehistoric time." Other authors, notably of the German school, consider that it was the chief cereal of ancient Egypt, Greece and Rome. At present its culture is largely limited to Switzerland, southern Germany, and Spain, being used for grits, coarse flour, and feeds.

MACROSCOPIC STRUCTURE.—The *spikelets* are loosely arranged on the rachis (or axis) as in common wheat, but on threshing, instead of the *kernels* falling out of the chaff leaving it on the rachis, the rachis breaks, usually just below the base of each spikelet, and a section remains attached and closely pressed to the inner side of the spikelet along half its length. The spikelets are irregularly four-sided, somewhat compressed. The stiff, broad, truncated, blunt-keeled *empty glumes* subtend two to three flowers, ripening usually two kernels. The thin, membranous, many-nerved *flowering glumes* may be awned or awnless; the *palets*, also thin, have two keels each with short stiff *bristles*. Carleton[1] gives an illustration showing well the characters of spelt and emmer.

MICROSCOPIC STRUCTURE.—The chaff resembles in some histological details barley, in others oats; the kernel is intermediate between wheat and rye with some details unlike either.

[1] U. S. Dept. Agr. 1911, Farm. Bul. 466.

Empty Glumes.—The four layers are as follows: (1) *outer epiderm* of wavy-walled elongated cells, twin cells (one more or less crescent-shaped) and round cells (some developed into hairs), (2) *hypoderm* of several thicknesses of thick-walled *sclerenchyma fibers*, (3) *spongy parenchyma*, and (4) *inner epiderm* much like the outer but with stomata added. The second layer is lacking on the edges and the third occurs only beneath the nerves.

Flowering Glume.—The structure is much like that of the empty glumes but the *sclerenchyma fibers* have thinner walls and form only one cell layer; the *spongy parenchyma* forms a continuous layer of rectangular cells; and the *inner epiderm* is made up of thin-walled elongated cells and here and there short awl-shaped *hairs* with swollen bases.

Palet.—Rows of thick-walled *hairs* up to 200 μ in length form a saw-edge on each keel and *spongy parenchyma* occurs only under the keels; in other respects the structure is practically the same as of the flowering glume.

Pericarp.—Spelt *hairs* reach 1500 μ or more in length and occasionally have a lumen broader than the walls, whereas wheat hairs are less than 1000 μ and the lumen is rarely broader than the walls. The *epicarp*, *hypoderm*, and *cross cells* have thick, distinctly pitted side walls, and the cross cells have thin, distinctly pitted end walls as in the corresponding layers of wheat. *Tube cells* occur in considerable number.

Spermoderm, Perisperm, Endosperm, and **Embryo** are little if any different from these parts in wheat.

Chief Structural Characters.—Grain chaffy; section of rachis at side of spikelet, not as in emmer forming a stem.

Chaff similar to barley chaff but saw-edge of stiff hairs on palets as in oats. Epicarp hairs longer (1500 μ) than in wheat, and lumen more commonly broader than walls. Other distinctions from wheat slight.

CHEMICAL COMPOSITION.—König's Compilation (human foods) and Dietrich and König's Compilation (feeds) give the average of 18 early analyses as: water **13.37,** protein **11.84,** fat **1.85,** nitrogen-free extract **68.22,** fiber **2.65,** and ash **2.07** per cent.

Proteins.—In Red Tyrol spelt König and Rintelen [1] found the three prolamines described under wheat but only the gliadin was obtained pure. It contained 17.72 per cent of nitrogen.

In a prolamine preparation from spelt, Jones, Gersdorff, and Moeller [2] found cystine 1.79 and tryptophane 1.08 per cent.

Pillitz[3] found 2.35 per cent of water-soluble protein (albumin) in air-dry spelt.

[1] Z. Unters. Nahr.-Genussm. 1904, **8,** 401, 721.

[2] J. Biol. Chem. 1924, **62,** 183.

[3] Z. anal. Chem. 1872, **11,** 46.

Carbohydrates.—In the sample mentioned in the foregoing sentence, Pillitz made the following determinations: sugar 0.99, dextrin 1.72, and starch 61.67 per cent.

EMMER

Triticum sativum Lam. var. *dicoccum* (Schrank) Hackel = *T. dicoccum* Schrank

Fr. Amidonnier. Ger. Emmer.

Heads of emmer have been found among the relics of the lake dwellers in Switzerland, in which country and adjoining parts of southern Germany it is still grown on a small scale. De Candolle considers it an ancient cultivated form of spelt. A sample of grain from a mummy of the dynasty of Amenophis III (1800 B.C.), obtained at Luxor by the late Mr. James S. Bell of the Washburn-Crosby Company, Minneapolis, appears to be emmer, although its ancient cultivation in Egypt has been disputed.

MACROSCOPIC STRUCTURE.—Emmer differs from spelt more in its habit of growth (in a closer spike) and the place where the rachis breaks (just above the point of attachment of the spikelet) than in the spikelet itself. By threshing, the section of the *rachis* forms a kind of stem to each spikelet from one-third to one-fifth its length and does not, as in spelt, extend along the side of the spikelet. The *spikelets* are also more compact and more flattened, the empty glumes taper more to the blunt apex, and the keel is a little sharper and ends in a sharper tooth than in spelt, but these differences are not well marked. Carleton's illustration [1] shows well the general appearance of the grain.

MICROSCOPIC STRUCTURE.—The structure of the chaffy parts corresponds to that of spelt.

Hauptfleisch [2] states that the epicarp *hairs* of emmer are more like those of rye than of wheat, with lumen often broader than the walls. This we are unable to confirm with the varieties we have examined. We do, however, confirm his statement that emmer *cross cells* are much thinner-walled than wheat cross cells and less distinctly porous; furthermore that the pits are perhaps even less distinct than in rye cross cells. On the other hand the end walls of these cells are thin and porous and do not have large intercellular spaces, therefore they lack the swollen appearance so characteristic of rye. Hauptfleisch correctly states that the starch is of the wheat type.

[1] U. S. Dept. Agr. 1911, Farm Bul. **466.**

[2] Landw. Vers.-Stat. 1903, **58**, 65.

Chief Structural Characters.—Grain chaffy; section of rachis at base forming stem not as in spelt on side.

Chaff elements practically like those of spelt. Cross cells with thin indistinctly beaded side walls but without swollen end walls. Otherwise like wheat in structure.

CHEMICAL COMPOSITION.—The composition of a foreign sample of black emmer and the range in composition and average of 24 analyses of black emmer grown in the United States, as obtained by Chamberlain,[1] follow:

Composition of Emmer (Chamberlain)

	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Foreign	8.92	12.00	1.47	71.93	10.72	3.88
United States:						
Min.	7.97	8.63	1.43	61.01	9.17	2.46
Max.	10.25	18.69	2.88	74.16	17.89	5.60
Aver.	**8.68**	**13.28**	**1.91**	**69.42**	**11.31**	**4.07**

Proteins.—In a prolamine preparation from emmer, Jones, Gersdorff, and Moeller[2] found cystine 1.98 and tryptophane 0.80 per cent.

EINKORN

Triticum monococcum L.

Fr. Petit épeautre. Ger. Einkorn.

Authorities are well agreed that this chaffy wheat, known usually by its German name meaning one-grain, is a distinct species. Vilmorin[3] has not succeeded in crossing it with varieties of *T. sativum*. De Candolle traces its origin to Serbia, Greece, and Asia Minor, where it still has been found wild. Gilg[4] states it was grown by the lake dwellers. It is cultivated at present on poor soil in Spain, Switzerland, and South Germany.

[1] U. S. Dept. Agr., Bur. Chem. 1909, Bul. **120.**

[2] J. Biol. Chem. 1924, **62,** 183.

[3] Bul. soc. bot. France, 1883, 62.

[4] Real-Enz. ges. Pharm. 2 Aufl. 1909, **12,** 315.

MACROSCOPIC STRUCTURE.—The terminal spikelet of the head is abortive in this species. *Empty glumes* are nerved and bear three teeth. The *flowering glume* splits longitudinally into two parts on ripening. The spikelets bear only one *kernel*, as is indicated by the name.

MICROSCOPIC STRUCTURE.—The chaff elements correspond closely with those of spelt and emmer but the tissues are more delicate, the awl-shaped *hairs* of the *inner epiderm* of the flowering glume are shorter, and the walls of that layer, especially over the nerves, are more or less wavy.

The *hairs* of the pericarp are like those of wheat. The *cross cells* are as thin-walled and as indistinctly beaded as in emmer or even more so.

According to Benecke,[1] einkorn is the only one of the chaffy wheats that shows a blue coloration in the contents of the aleurone cells. This blue color is faint.

Wiesner[2] and Hauptfleisch[3] agree as to the maximum size of the starch grains, giving 27 and 28.5 μ respectively.

CHIEF STRUCTURAL CHARACTERS.—Spikelet with only one fruit.

Chaff tissues more delicate and hairs of inner epiderm shorter than in spelt and emmer. Epicarp hairs of wheat type; cross cells indistinctly beaded. Aleurone cells with faint blue contents. Starch small (28 μ).

CHEMICAL COMPOSITION.—Four analyses by Chamberlain[4] yielded minimum, maximum, and average results as follows:

COMPOSITION OF EINKORN (CHAMBERLAIN)

	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	7.86	13.69	2.00	61.64	13.01	4.72
Max.	8.81	16.25	2.43	66.15	14.67	6.82
Aver.	**8.34**	**14.67**	**2.19**	**64.02**	**13.55**	**5.57**

Proteins.—Jones, Gersdorff, and Moeller[5] found in einkorn prolamine 1.98 per cent of cystine and 0.47 per cent of tryptophane.

[1] Landw. Vers.-Stat. 1889, **36**, 337.
[2] Die Rohstoffe des Pflanzenreiches, 1 Aufl. Leipzig, 1873, p. 596.
[3] Landw. Vers.-Stat. 1903, **58**, 88.
[4] U. S. Dept. Agr., Bur. Chem. 1909, Bul. **120**.
[5] J. Biol. Chem. 1924, **62**, 183.

RYE

Secale cereale L.

Fr. Seigle. Sp. Centeno. It. Segala. Ger. Roggen.

Although not of the same genus, rye is closely related to wheat. It is more northern in its requirements than wheat and until modern times was not found wild or cultivated outside of central and northern Europe. In Germany, Austria, Switzerland, and eastward at the present time it ranks with wheat in importance as a bread cereal. It must also have been a common product in the British Isles for some centuries from whence it was introduced into North America. As late as the latter half of the nineteenth century rye was grown almost to the exclusion of wheat in New England and ground locally for bread-making. The influx of Teutonic and Scandinavian emigrants into the United States has stimulated its culture in middle western and northwestern states.

MACROSCOPIC STRUCTURE.—The *kernel* is more slender than wheat, tapers more toward both ends, and has a less inviting dirty brown or green-brown color. To the naked eye it shows no difference from wheat in morphological structure.

MICROSCOPIC STRUCTURE.—Its microscopic as well as macroscopic structure is best understood by comparison with its near relative, wheat. Such a study of comparative anatomy further aids in distinguishing the products of the two cereals—flour, bread, shorts, and bran.

Pericarp (Fig. 99, *F*; Fig. 100).—A cross section shows the same number of layers as in wheat and similar details of structure. The layers are: (1) longitudinally elongated *epicarp* cells (*epi*, *epi*[2]) with walls thinner and less distinctly porous (beaded) than in wheat, the cells at the apex being isodiametric (*epi*[1]) and interspersed with broad-lumened *hairs* (*t*); (2) *hypoderm* (*hy*) of one or two cell layers similar to the epicarp; (3) curious *intermediate cells* (*int*) with beaded or simple cell walls and round intercellular spaces; (4) *cross cells* (*tr*) with indistinctly porous side walls, rounded and swollen end walls, and (seen in cross section) inner wall thicker than outer; and (5) *tube cells* (*tu*).

The *hairs* have been the subject of much study by Wittmack[1] and others, as they furnish one means of distinguishing rye from wheat products. As a rule, but not always, the breadth of the lumen of these hairs is greater than the breadth (apparent breadth, strictly speaking, the thickness) of the walls. Often the lumen is of considerable breadth even at the apex of the hair. The length varies up to over 800 μ.

[1] Anleitung z. Erkennung organ. u. unorgan. Beimengungen im Roggen- u. Weizenmehle. Leipzig, 1884.

The second distinction of rye from wheat lies in the cell walls of the *epicarp* and *hypoderm* which are thinner and less sharply beaded.

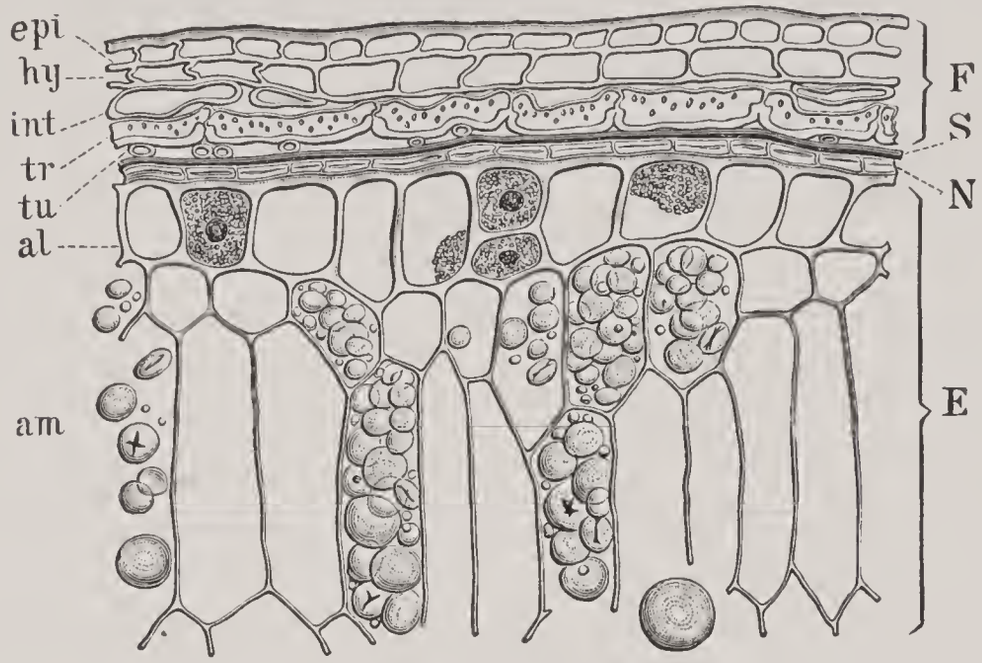


Fig. 99.—Rye. Kernel in median dorsal cross section. *F* pericarp: *epi* epicarp, *hy* hypoderm, *int* intermediate cells, *tr* cross cells, *tu* tube cells (endocarp). *S* spermoderm of two brown layers. *N* perisperm. *E* endosperm: *al* aleurone cells, *am* starch cells. ×160. (A.L.W.)

The third distinction and the most important is the structure of the *cross cells* (Fig. 101) which, like the outer layers, have thinner and less

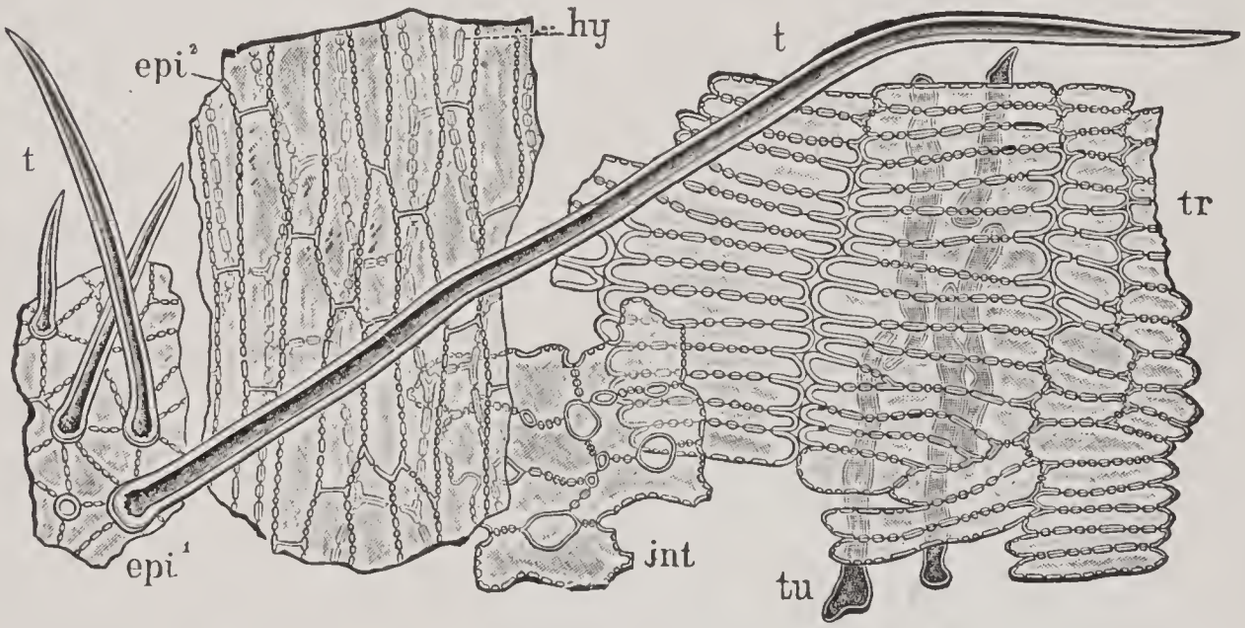


Fig. 100.—Rye. Pericarp layers in surface view. *epi*¹ epicarp at apex of grain with *t* hairs. Layers on middle of dorsal side: *epi*² epicarp, *hy* hypoderm, *int* intermediate cells, *tr* cross cells, *tu* tube cells. ×160. (A.L.W.)

distinctly porous side walls and in addition what appear to be swollen and rounded end walls without pores, whereas the end walls in wheat are not only thinner than the side walls but are distinctly porous. The

reason for this peculiar appearance will be apparent on comparing the cells (*tr*) in cross section and in surface view. Fig. 99 shows that the inner wall is thicker than the outer and that it turns upward at the end, continuing as a thickened radial wall part way to the outer wall, whereas Fig. 101 shows that intercellular spaces occur between the end walls. A careful study of mounts of scrapings from the two cereals will give a clear idea of this distinction.

The *intermediate cells*, as shown in Fig. 100 (*int*), suggest their morphological significance. It will be noted that the fragment shown is of cells somewhat elongated and arranged side by side in rows like cross cells. They are in fact the remains of an *outer cross-cell layer*, and their occurrence in both wheat and rye shows that these, like barley, have two cross-cell layers, hitherto thought to be a peculiarity of barley alone.

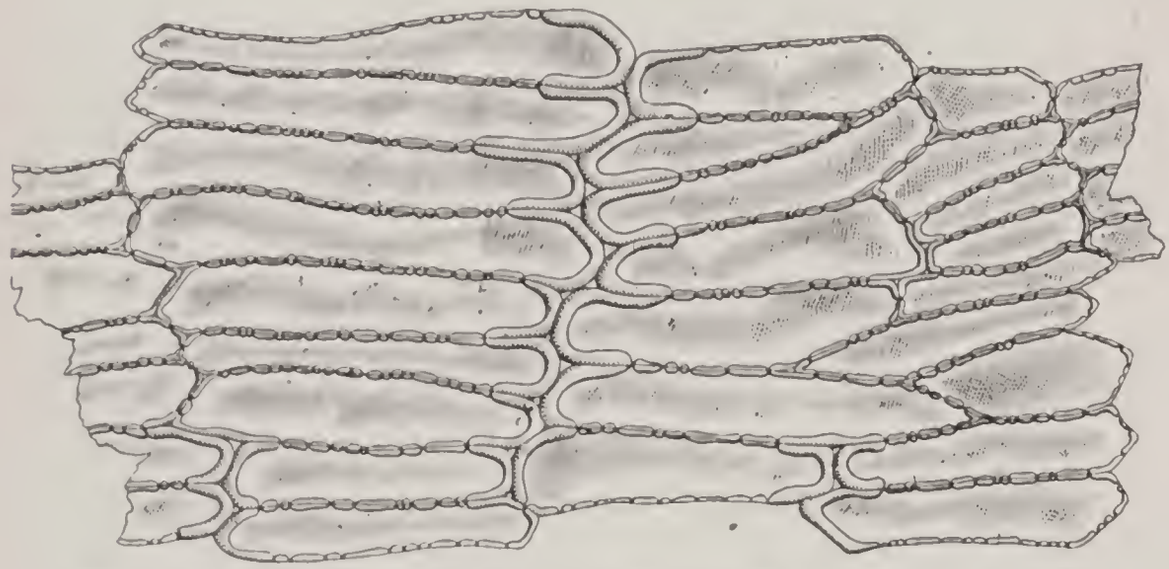


FIG. 101.—Rye. Cross cells in surface view. ×300. (A.L.W.)

Spermoderm (Fig. 99, *S*).—As in wheat this consists of two crossing layers of cells with exceedingly narrow walls, the inner layer darker than the outer, appearing as thin, colored bands in cross section.

Perisperm (Fig. 99, *N*).—This also is as in wheat and its structure is demonstrated as described under that head.

Endosperm (Fig. 99, *E*).—The *aleurone layer* in form, size, and structure of contents is practically the same as in wheat. Various slight distinctions between these cells in wheat and rye have been advanced but most of them do not appear to deserve mention. The difference in the size of the false aleurone grains, or better stated, the size of the protein meshes, noted by Von Höhnel and Berthold and given wide publicity, as stated under Wheat, does not seem decisive.

A really important characteristic is the blue color of the cell contents, brought to notice by Körnicke and Werner [1] and studied later by

[1] Handbuch des Getreidebaues. Berlin, 1885.

Benecke,[1] to which, seen through the more or less yellow outer layers, the kernel owes its greenish cast. Not all the aleurone cells have this color, but Benecke finds that some of the cells in all the varieties examined gave positive results whereas all varieties of wheat gave negative results. Of related wheats only emmer resembles rye in this respect, the color being, however, faint.

The *starch cells* contain starch grains of the wheat type, their average and maximum size being somewhat larger. An accurate numerical expression of the size in both cereals is not possible as is evidenced by the widely discrepant figures reported by different authorities. On the whole, Moeller's statement that in rye considerable numbers exceed 50 μ, whereas in wheat few reach 50 μ, seems sufficient. The presence of slits or radiating fissures, often found in rye starch grains, has been considered by some as sufficiently constant as to warrant using this character in diagnosis. We do not find it reliable since wheat starch also may have them and rye starch sometimes does not. A more decisive distinction of rye from wheat, which should always be used to confirm the results of histological examination, is the absence of gluten as noted below.

Chief Structural Characters.—Kernel more slender and pointed than wheat; dirty or greenish.

Hairs usually with lumen broader than walls (wheat narrower than walls); epicarp and hypoderm with indistinctly beaded walls; cross cells with indistinctly beaded side walls and swollen end walls (wheat with distinctly beaded walls throughout). Aleurone cells with blue contents; starch grains lenticular often over 50 μ (wheat seldom 50 μ).

MICROSCOPY OF RYE PRODUCTS.—The methods are described under Wheat. In the examination of *bran* and other mill by-products the characters noted above apply and may be readily determined by direct examination. *Whole kernel bread* or " pumpernickel " in addition to direct examination should be treated by the fiber method to remove starch, etc. as a preliminary step.

Foreign flours, excepting wheat and barley flour, are readily detected by the characters of the starch grains; wheat flour is best detected by the Bamihl test and an examination of the tissues accumulated as directed for the fiber test or the scum test.

CHEMICAL COMPOSITION.—Wheat and rye are similar in composition as well as structure, the similarity being shown not only by group analyses but also by the nature and characteristics of the components of the groups.

Following in tabular form are figures showing the composition of American rye in three periods, as given in U. S. Department of Agri-

[1] Landw. Vers.-Stat. 1889, **36**, 337.

culture publications, namely, prior to 1881, compiled by Jenkins and Winton,[1] during 1886, reported by Richardson,[2] and during 1909, reported by Chamberlain.[3] For comparison König's averages for German rye are also given.

Composition of Rye

	Samples	Water	Protein (N × 6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
United States (1878–1881):	5						
Min.		8.68	9.50	1.39	71.21	1.40	1.75
Max.		13.17	12.07	2.07	73.91	2.06	1.94
Aver.		11.59	10.58	1.66	72.64	1.67	1.86
United States (1886):	61						
Min.		6.85	9.28	1.38	68.74	1.10	1.31
Max.		11.60	15.58	2.91	77.54	1.95	3.72
Aver.*		13.37	12.03	1.84	69.64	1.36	1.76
United States (1909):	17						
Min.		8.88	10.50	1.54	76.01	2.07	1.65
Max.		9.92	17.44	2.17	83.71	2.66	3.06
Aver.		9.38	13.44	1.83	80.24	2.30	2.18
Germany (before 1903):	119						
Aver.*		13.37	11.17	1.63	69.12	2.62	2.09

* Reduced to König's basis of 13.37 per cent of water.

It would appear, if these analyses are representative, that the protein content of American-grown rye has increased during the past quarter century and that it now considerably exceeds that of German-grown rye.

Rye Flour.—Notwithstanding the markedly higher protein content of American rye over German rye, such few analyses as are available would seem to indicate no such advantage of American rye flour.

Four analyses of *rye flour*, reported in the U. S. Census of 1880,[4] and 8 analyses, including perhaps the foregoing, summarized by Atwater and Bryant,[5] show the results given on the following page.

Comparison of the protein content in the above table with that of German rye flour, which according to König is about 3 per cent higher, and with that of the rye grain indicates that the milling was so con-

[1] Off. Exp. Sta. Bul. 11.
[2] Div. Chem. Bul. 9.
[3] Bur. Chem. Bul. 120.
[4] 3, 423.
[5] U. S. Dept. Agr., Off. Exp. Sta., Bul. 23 rev.

Composition of American Rye Flour

	Samples	Water	Protein (N × 6.25)	Fat	N-f.ext.	Fiber	Ash
		%	%	%	%	%	%
Analyses before 1881:	4						
Min.		12.35	6.00	0.78	77.56	0.35	0.64
Max.		13.58	7.05	0.89	79.09	0.45	0.77
Aver.		**13.10**	**6.65**	**0.84**	**78.28**	**0.41**	**0.72**
Analyses before 1906:	8						
Min.		11.90	4.90	0.20	77.60	0.40	0.60
Max.		13.60	8.80	1.30	80.20	0.50	0.90
Aver.		**12.90**	**6.80**	**0.90**	**78.70**	**0.40***	**0.70**

* Fiber determinations only in part of the samples.

ducted as to include in the flour only the more starchy part (as distinguished from the horny part) of the kernel. The high ash content in conjunction with such a low protein content may be due to lack of certain precautions in burning which in early analyses was not deemed essential. Analyses showing the composition of rye and its products from the same milling, following modern processes, would be instructive.

That rye bread is not inferior in protein content to wheat bread is indicated by analyses given under that head.

Rye Offal.—Among the many analyses of rye by-products made in connection with state feed inspection, the following by Kellogg[1] show respectively the composition of *middlings* (average of 2 analyses) and *mixed middlings* and *bran* (1 analysis): water 9.76 and 10.84, protein 16.78 and 16.69, fat 3.31 and 3.52, and fiber 5.66 and 5.12 per cent.

Rye Embryo.—An analysis of pure rye embryo (*germ*) by Kling[2] follows: water 14.7, water-soluble protein 9.5, water-insoluble protein 26.18, amides 3.82, total protein 39.5, free fatty acids 1.74, total fat 10.57, nitrogen-free extract 27.99, fiber 2.24, pentosans 6.86, lime 0.05, phosphoric acid 2.97, and ash 5.00 per cent; starch none.

As analyzed by Kalning,[3] rye embryo contained the following percentages calculated to the dry substance: protein, total 44.74, soluble in water 21.55, soluble in 60 per cent alcohol 5.55; fat 11.95; nitrogen-free extract 33.83; starch 6.00 *circa*; sugar, reducing 6.66, after inversion 22.62; pentosans 7.32; ash 5.54; phosphoric acid, total 3.11, water soluble 1.75; and aqueous extract 51.44 per cent.

[1] Pennsylvania Dept. Agr., Bur. Chem. 1913, Bul. **249.**

[2] Landw. Vers.-Stat. 1910, **72**, 427.

[3] Z. ges. Getreidew. 1917, **9**, 167.

Koehler [1] found in the dried embryo 3.11 per cent of P_2O_5 and after ether extraction 3.55 per cent, of which about 44 per cent was phytin and 11 per cent was in mineral form. Certain enzymes in the embryo decompose phosphorus-organic compounds.

Proteins.—The one marked distinction of rye from wheat, as regards the proteins, is the failure of the former to yield gluten. Neither Ritthausen [2] nor Osborne,[3] both of whom studied the proteins of the two cereals, satisfactorily explained this difference nor was either able to obtain a pure glutelin or salt insoluble protein from rye. By analogy one would expect such a protein to exist and be similar to or identical in chemical configuration with the glutenin of wheat. Accepting this hypothesis, the failure to combine with gliadin to form glutenin may be explained as due to physical condition or lack of an unknown constituent, whether or not an enzyme, essential for bringing about the union.

Richardson,[4] in the examination of 16 varieties of rye prior to Osborne's investigation, found 1.76 to 3.45 per cent of protein soluble in 80 per cent alcohol (crude gliadin) and from 7.60 to 9.97 per cent insoluble in that menstruum. The alcohol-soluble portion would appear to represent an incomplete extraction as it reaches in no case the amount of gliadin Osborne found.

Osborne[5] found the following amounts of proteins in whole rye flour.

Proteins of Whole Rye Flour (Osborne)

	%
Leucosin (water-soluble)	0.43
Edestin (brine-soluble) and proteose	1.76
Gliadin (alcohol-soluble)	4.00
Glutelin (brine-insoluble) by difference	2.44
	8.63

The specific rotation of rye gliadin in 55 per cent alcohol, as found by Kjeldahl,[6] is $-121°$. The results of Lindet and Ammann,[7] who separated rye gliadin into two parts each with different rotatory power, are not comparable.

More recently Csonka and Jones,[8] who have studied the glutelins of the cereals, have precipitated from a 0.2 per cent sodium hydroxide

[1] Bul. intern. acad. Polonaise 1929, **B**, 237.
[2] J. prakt. Chem. 1886, **99**, 439.
[3] J. Am. Chem. Soc. 1895, **17**, 429.
[4] Loc. cit.
[5] Loc. cit.
[6] Bied. Zentr. 1896, **25**, 197.
[7] Bul. soc. chim. 1907, **1**, 968.
[8] J. Biol. Chem. 1929, **82**, 17.

extract of rye, by the addition of ammonium sulphate to 5 per cent saturation, a *glutelin* with an isolectric point of *p*H 6.2. The ammonium sulphate added was in excess of that needed for its separation, which was 3 per cent. The filtrate from the glutelin contained another protein precipitated when ammonium sulphate was added to 32 per cent saturation. It was doubtless a globulin.

The *Ultimate Composition* of the three proteins which Osborne [1] obtained in a condition of purity and of the glutelin isolated by Csonka and Jones [2] follows:

	Leucosin (Osborne)	Edestin (Osborne)	Gliadin (Osborne)	Glutelin (Csonka and Jones)
	%	%	%	%
Carbon	52.97	51.19	52.75	53.05
Hydrogen	6.79	6.74	6.84	6.35
Nitrogen	16.66	18.19	17.72	16.72
Sulphur	1.35	23.88	1.21	1.12
Oxygen	22.23		21.48	22.76
	100.00	100.00	100.00	100.00

Amino Acids of Rye Proteins.—By hydrolysis of rye gliadin, Osborne and Clapp [3] obtained the following results:

Products of Hydrolysis of Rye Gliadin (Osborne and Clapp)

	%
Glycocoll	0.13
Alanine	1.33
Leucine	6.30
Serine	0.06
Aspartic acid	0.25
Glutamic acid	33.81
Tyrosine	1.19
Phenylalanine	2.70
Proline	9.82
Tryptophane	present
Arginine	2.22
Histidine	0.39
Ammonia	5.11
	63.31

Valine and cystine were not isolated.

[1] Loc. cit.

[2] Loc. cit.

[3] Am. J. Physiol. 1908, **20**, 494.

These figures correspond closely with those obtained by the same authors and the same method for wheat gliadin. Taken in conjunction with the ultimate analysis and the specific rotation they seem to warrant the conclusion of both Osborne and Plimmer that the gliadins of the two cereals are identical. The percentage of hydrolysis products of wheat gliadin, as given under wheat, are revised figures obtained during later studies. A revision in the case of rye gliadin has not been undertaken.

Jones, Gersdorff, and Moeller[1] in two preparations of rye gliadin found:

	Cystine	Tryptophane
	%	%
I	2.64	0.36
II	2.61	0.75

The basic amino acids of rye glutelin were determined by Csonka and Jones[2] with the following results: cystine 2.56, arginine 7.07, lysine 5.39, and histidine 2.75 per cent.

Nitrogen Distribution in Rye Glutelin.—The authors named in the preceding paragraph secured by Van Slyke's method the following figures in terms of percentages of the total nitrogen:

	%
Humin N	1.62
Cystine N	1.79
Arginine N	13.61
Lysine N	6.18
Histidine N	4.46
Amino N in filtrate	55.53
Non-amino N in filtrate	4.78
Amide N	10.87
	98.84

Nitrogen Distribution in Rye.—Nollau[3] has applied to rye Van Slyke's method for the determination of the nitrogen distribution in eight groups with the results shown on the following page.

The high histidine nitrogen (10.48 per cent) compared with that of wheat (1.67 per cent) as found by Grindley and Slater and of wheat and

[1] J. Biol. Chem. 1924, **62**, 183.

[2] Loc. cit.

[3] J. Biol. Chem. 1915, **21**, 611.

	%
Humin N	1.54
Cystine N	2.20
Arginine N	10.49
Lysine N	1.24
Histidine N	10.48
Mono-amino N	37.96
Non-amino N	21.63
Amide N	15.00
	100.54

rye proteins as found by Osborne and Clapp and by Csonka and Jones needs explanation.

With the data now at hand, rye glutelin, if a single substance, would not appear to be identical with the glutenin of wheat, thus furnishing an explanation for our inability to obtain gluten from rye flour. It should be remembered, however, that many of the data were secured early in the present epoch of protein research when the methods had not been perfectly developed.

Free Amino Acids, Acid Amides, and Polypeptides.—Determinations by Jodidi and Wangler [1] appear in the following table:

Distribution of Non-protein Nitrogen in Rye (Jodidi and Wangler)

	Acid amide N	Amino acid N	Peptide N
	%	%	%
In oven-dried rye:			
North Dakota	0.090	0.075	0.162
Von Rümker	0.093	0.101	0.155
Reg. Rosen	0.069	0.099	0.070
In total nitrogen:			
North Dakota	3.72	3.09	6.69
Von Rümker	4.96	5.39	8.30
Reg. Rosen	4.14	5.97	4.21

Fat (Ether Extract).—Meyer [2] determined the constants of the fat of the entire grain with the following results: specific gravity at 16° C. 0.9334, refractive index at 28° C. 1.4767, saponification number 196, iodine number 81.88, acid number 4.06, neutralization value of fatty acids 199, insoluble acids and unsaponifiable matter 88.8, solidifying

[1] J. Agr. Res. 1925, **30**, 989.

[2] Chem. Z. 1903, **27**, 958.

point of fatty acids 34° C., melting point of fatty acids 36° C., and iodine number of insoluble fatty acids 1.3.

Alpers[1] quotes some of Meyer's figures and gives the following for rye embryo oil: specific gravity at 15° C. 0.9322, refractive index at 25° C. 78.5, solidifying point −15° C., saponification number 174.3, iodine number 127.7, Reichert-Meissl number 0.33, and Hehner number 96.01.

Kling[2] found 10.57 per cent of total fat in the starch-free embryo.

Stellwaag[3] found 3.31 per cent of *lecithin* in the fat of rye bran.

Sterols.—Probably these are the same as or similar to those of wheat, but definite data are lacking.

Carbohydrates.—Some of the early investigators of the carbohydrates of the cereals found much larger amounts of the soluble forms than have been obtained more recently with improved methods that avoid enzyme action during extraction and other errors. Banister[4] reported in rye 4.30 per cent of sucrose or almost twice that in wheat. Richardson[5] in the samples of air-dry rye found as follows: sugar, etc., 6.20 to 9.46, dextrin, etc., 4.14 to 6.02 and starch 58.73 to 64.34 per cent. Stood,[6] in rye of different farms and years, obtained the following somewhat lower but still considerable figures: dextrose 1.10 to 3.38, dextrin 3.01 to 5.24, starch 54.24 to 68.88, and other constituents of the nitrogen-free extract 5.79 to 18.79 per cent.

Although it is well known that such analyses represent group separations rather than determinations of chemical individuals, it is not surprising that the high figures were discredited and that some even disputed the presence of any sucrose in cereal grains. That *sucrose* is a constituent of rye was proved by Schulze, who separated 0.15 gram in crystalline form from 3 kilos of ground rye.

Krug[7] found in rye as follows: invert sugar 0.068, sucrose 0.416, and dextrin 0.220 per cent. These correspond closely with the figures Stone obtained in the analysis of wheat.

Raffinose is said to occur in rye as well as wheat.

Secalose, according to Schulze and Frankfurt,[8] is present in immature rye grain in amounts varying from 2 to 3 per cent.

Trifructosan.—Tillmans, Holl, Jariwala,[9] by adding dilute alkali

[1] Ibid. 1918, **42**, 37.
[2] Loc. cit.
[3] Landw. Vers.-Stat. 1890, **37**, 133.
[4] Chem. News 1885, **52**, 293.
[5] Loc. cit.
[6] Landw. Vers.-Stat. 1891, **38**, 89.
[7] U. S. Dept. Agr., Div. Chem. 1898, Bul. **13**, 1207.
[8] Ber. 1894, **27**, 65, 3525.
[9] Z. Unters. Nahr.-Genussm. 1928, **56**, 26.

to the 70 per cent alcoholic extract of rye flour, precipitated trifructosan ($C_{18}H_{30}O_{15}$), the anhydride of trifructose. The purified substance is white, crystalline, and slightly sweet. It contains 43.38 per cent of carbon and 6.43 per cent of hydrogen. Its specific rotation at 20° C. is direct −43.93°, after inversion −92.70°.

Kruisheer [1] obtained in bolted rye meal 1.5 to 2.0, in wheat flour only 0.1 to 0.3 per cent of trifructose anhydride, and states that the amount of rye flour in a mixture may be determined within 10 per cent.

Pentosans.—The literature on pentosans in rye is meager. A determination in a single sample of rye made in the Bureau of Chemistry [2] gave 8.10 per cent, which is over 2 per cent more than was obtained in the same laboratory in a sample of wheat.

Phosphorus-Organic Compounds. *Lecithin.*—Schulze [3] states that rye contains 0.57 per cent of lecithin in the dry substance, and Alpers [4] states that rye embryo contains 2.43 per cent, both figures being slightly lower than the amounts given by the same authors as occurring in wheat and wheat germ respectively.

Phytin and *Nucleic Acid.*—See Wheat.

Enzymes.—*Maltase* was found by Wierzchowski [5] to be present in small amount.

Protease. According to Giesen,[6] the kernel contains 0.50 and the bran 0.9 per cent calculated as trypsin, the optimum temperature being 30 to 45° C.

Mineral Constituents.—The average composition of the ash of rye grain as obtained by Wolff [7] follows:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%
32.1	1.5	2.9	11.2	1.2	47.9	1.3	1.4	0.5

Minor Mineral Constituents. *Iron.*—Whole kernel 33 to 44 mg. per kilo (Bunge).[8]

Aluminum.—Rye 5.6 mg. per kilo, dry basis (Bertrand and Lévy).[9]

[1] Rec. trav. chim. 1931, **50**, 153.
[2] U. S. Dept. Agr., Bur. Chem. 1898, Bul. **13**, 1203.
[3] Landw. Jahrb. Schweiz 1892, **6**, 72.
[4] Loc. cit.
[5] Biochem. Z. 1913, **57**, 125.
[6] Inaug. Dis. Bern, 1909.
[7] Aschenanalysen, 1880.
[8] Sherman's Compilation; U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.
[9] Compt. rend. 1931, **192**, 525.

Manganese.—Rye 14.2 mg. per kilo, air-dry basis (Quartaroli);[1] 105 to 157 mg. per kilo, dry basis (Davidson).[2]

Copper.—Rye 7.5 mg. per kilo, air-dry basis (Guerithault);[3] 4.16 mg. per kilo, air-dry basis (Quartaroli).[1]

Zinc.—Rye 17.2 mg. per kilo, air-dry basis (Birckner);[4] 13.5 mg. per kilo, dry basis (Bertrand and Benzon).[5]

CHEMICAL COMPOSITION OF BREAD. Common Rye Bread.—The idea that rye bread is more nutritious than wheat bread is quite widespread, particularly among German emigrants, who regard it as the mainstay of the sturdy German peasant, and among the older New England farmers who remember the time when bread from stone-ground rye flour was on every table. Light is thrown on this subject by the following minimum, maximum, and average results of analyses of American rye bread as tabulated by Atwater and Bryant:[6] water 20.6 to 44.0, aver **35.7** per cent; protein ($N \times 6\frac{1}{4}$) 6.4 to 11.1, aver. **9.0** per cent; fat 0.01 to 1.4, aver **0.6** per cent; nitrogen-free extract 45.6, to 65.8, aver. **53.2** per cent; fiber 0.1 to 1.0, aver **0.5** per cent; ash 0.6 to 2.7, aver. **1.5** per cent.

Compared with the summary of 111 analyses of wheat bread by the same compilers, the water and protein content are about the same in both. This correspondence and the similarity in composition of wheat and rye grains leave the manifest difference in analyses of rye and wheat flour, already noted, to be explained.

The analyses of the rye flour are possibly not fully representative of the product at the time the bread was analyzed. A more significant explanation is the fact that both the miller and the baker, then and now, are accustomed to mix rye flour with a second or third grade of wheat flour containing a liberal percentage of protein. By this means the loaf volume is improved although not to such an extent as when a higher grade flour is added.

Whole Rye Bread (Pumpernickel) forms a dark, heavy loaf with the following average composition: water 50.7, protein 11.9, fat 0.6, nitrogen-free extract 35.9, fiber 1.2, and ash 0.9 per cent (Atwater and Bryant).

[1] Ann. chim. appl. 1928, **18**, 47.
[2] Cereal Chem. 1929, **6**, 128.
[3] Compt. rend. 1920, **171**, 196.
[4] J. Biol. Chem. 1919, **38**, 191.
[5] Bul. soc. hyg. aliment. 1928, **16**, 457.
[6] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

TWO-ROWED BARLEY

Hordeum sativum Jess. var. *distichon* (L.) Hackel = *H. distichon* L.

Fr. Orge à deux rangs. Sp. Cebada ladilla. It. Orzo. Ger. Zweizeilige Gerste.

A wild form of barley, known as *H. sponteneum* Koch., found growing in various parts of western Asia, appears to be the parent from which all the cultivated types of barley have been derived whether through evolution or cultivation. The varieties of two-rowed barleys now grown, if not the same species as the wild form, are at least closely allied. This type was cultivated by the lake dwellers although not to the same extent as six-rowed varieties. There is no evidence that it was grown in Egypt, where specimens of six-rowed barley have been found in the oldest tombs.

In central and northern Europe, also in certain regions of the United States, two-rowed barley is the type most commonly cultivated, being well adapted for malting.

MACROSCOPIC STRUCTURE.—The one-flowered *spikelets* of all types of barley are in fan-like groups of three, alternating on opposite sides of the jointed zigzag rachis. In the two-rowed type only the middle spikelet is fertile. Each spikelet has two slender or awl-like *glumes*, both on the side away from the rachis. According to Hochsteter,[1] these are parts of a single empty glume formed by splitting, the other belonging on the opposite side being entirely lacking. Both *empty glumes* are left on the head on threshing, the grain of the common or chaffy varieties, as it enters commerce, consisting of the *kernel* closely enveloped by the *flowering glume* and *palet*.

Naked varieties, analogous to wheat and rye, differ from the chaffy varieties in that the flowering glume and palet remain on the rachis on threshing, the grain being easily detached.

Contrary to the statement of Tschirch and Oesterle,[3] both the *flowering glume* and *palet* of all the chaffy varieties examined by us, including some of the best known, such as Chevalier, Hanna, and Orel, are grown to the pericarp and not as in spelt and oats merely tightly held without being adherent, although this does not preclude the existence of varieties intermediate between the chaffy and the naked types in which the grain is merely held and not grown to the chaff.

The *kernel* (Figs. 102 and 103), enveloped by the chaff, is strongly spindle-shaped and ordinarily of a buff color. The *flowering glume* is

[1] Flora 1848.

[2] Anatomischer Atlas. Leipzig, 1900, p. 177.

five-ribbed, the central rib of the bearded varieties, as harvested, being extended as a long awn which afterwards breaks off on threshing. The *palet*, closely clasped by the edges of the flowering glume, is two-keeled. On the palet side over the groove is the rudiment of the stem (rachilla) of an abortive flower forming a *bristle* about one-third the length of the kernel. Within the flowering glume are two minute *lodicules*, downy with long hairs.

The *embryo*, as in wheat and rye, is on the dorsal side extending about one-third of the distance to the apex; the *groove* is beneath the palet. Although the general structure of the embryo is the same as of wheat, the number of secondary radicles is greater. According to Harz,[1] who refers to earlier investigators, there are four to nine. Unlike that of

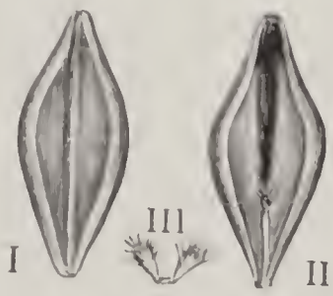


Fig. 102.

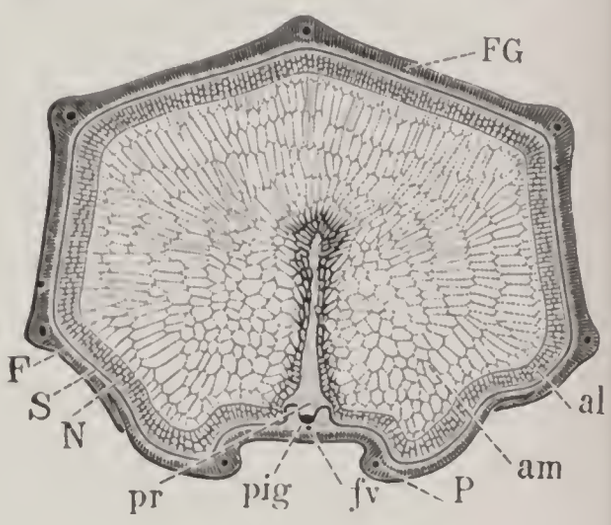


Fig. 103.

Fig. 102.—Barley. I dorsal side showing three ribs of flowering glume. II ventral side showing edges of flowering glume clasping palet, also bristle at lower end of palet groove. III lodicules from base within flowering glume. ×2. (A.L.W.)

Fig. 103.—Barley. Kernel and chaff in cross section. *FG* flowering glume, with five ribs, clasping *P* palet with two keels; *F* (gray) pericarp; *S* (black line) spermoderm broadening into *pig* pigment strand; *fv* fibro-vascular bundle of raphe; *N* (white) perisperm broadening into *pr* perisperm strand extending into center of kernel; *al* aleurone layer; *am* starch cells. ×15. (A.L.W.)

wheat, the groove proper, even after removal of the chaff, is broad and shallow. Figure 103 shows the extension of the perisperm and aleurone cells into the center of the starchy endosperm. This at first sight might seem to be a narrow groove, as in wheat, but it will be noted that it is beneath the groove proper and corresponds to the two bends in the tissues of wheat located both sides of the arms of the Y.

MICROSCOPIC STRUCTURE.—Disregarding the empty glumes and the awns which are eliminated in threshing and winnowing, the parts to be studied are (1) the *chaff*, consisting of *bristle, flowering glume, palet*, and *lodicules* and (2) the *kernel* or caryopsis, consisting of *pericarp, spermoderm, perisperm, endosperm*, and *embryo*.

[1] Samenkunde, 1885.

Naked barleys differ from the chaffy varieties in their histology chiefly as regards the epicarp and hypoderm, which are more robust and, as seen in cross section, not collapsed, the hypoderm forming often several distinct layers.

Cross sections are cut through the whole kernel without removing the flowering glume and palet; surface preparations are secured by scraping.

Bristle or Rachilla (Figs. 104 and 105).—Whatever traces of an abortive flower may have been present at earlier stages of development, the bristle at maturity shows no evidence of such. Its *epidermal cells* and stiff *hairs* are striking.

The *epidermal cells* (Fig. 104), like those of the outer epiderm of the flowering glume and palet, consist of thick, wavy-walled, elongated cells; twin cells, one crescent-shaped, the other round; and round cells.

Fig. 104.

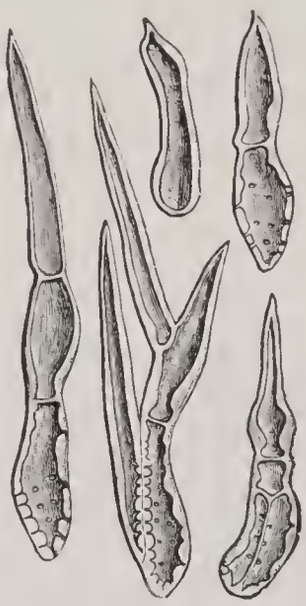


Fig. 105.

Fig. 104.—Barley. Tip of bristle showing epiderm and stiff hairs. ×160. (A.L.W.)

Fig. 105.—Barley. Hairs of various types on bristle below apex. ×160. (A.L.W.)

The *hairs* (Fig. 104) at the apex of the bristle, compared with those on other parts of the grain, are remarkably robust, the breadth at the base reaching over 60 μ and the thickness of the walls 10 μ; the length varies up to 1 mm. or more. Other characters are the rather blunt points and the globular bases with pitted walls. Below the apex the hairs (Fig. 105) are smaller but still of sturdy build. They are remarkable for their curious unicellular, jointed, and branching forms.

Flowering Glume (Fig. 106, *G*; Fig. 107).—Except at the apex and on the edges there are four layers: (1) *outer epiderm* (*aep*, *aep*^{3}), consisting of elongated, wavy-walled cells with twin cells, one crescent-shaped, the other oval, and round cells; (2) *sclerenchyma fibers* (*f*, *f*^{1}, *f*^{2}) with both thick and thin walls and both round and diagonal pores; (3) *spongy parenchyma* (*p*) of characteristic irregularly square or quadrilateral cells through which run the *fibro-vascular bundles* (*fv*) of the ribs; and (4) *inner epiderm* (*iep*) with large more or less polygonal cells, awl-shaped hairs, and stomata.

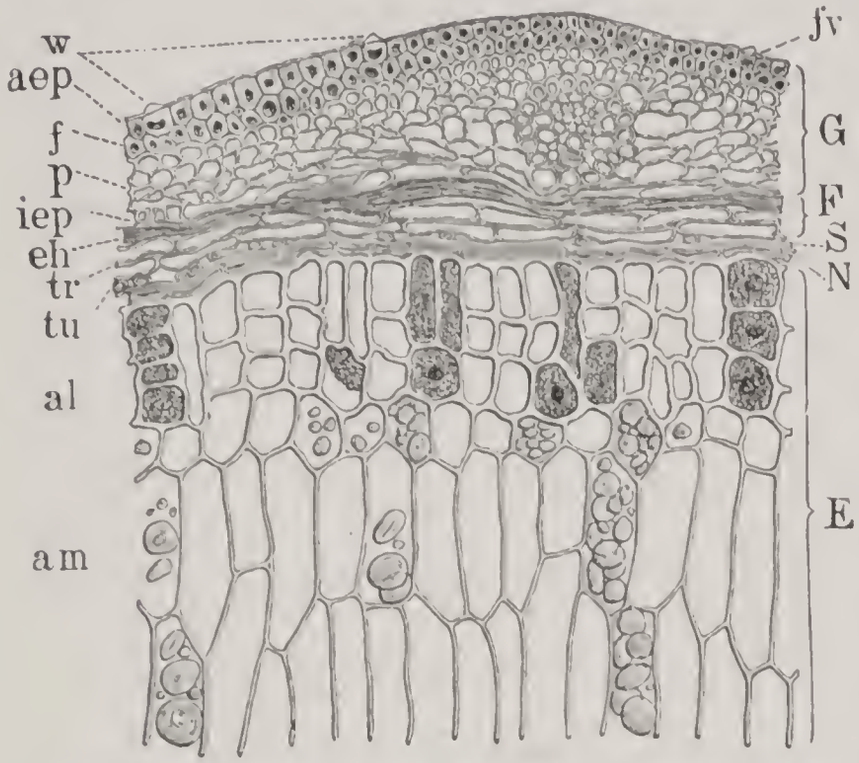


Fig. 106.—Barley. Kernel and chaff in median dorsal cross section. *G* flowering glume: *aep* outer epiderm with *w* cuticular warts, *f* fiber layer, *p* spongy parenchyma with *fv* fibro-vascular bundle of nerve, *iep* inner epiderm. *F* pericarp: *eh* epicarp and hypoderm, *tr* cross cells, *tu* tube cells. *S* spermoderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *am* starch cells. ×160. (A.L.W.)

Moeller[1] and Emmerling[2] call special attention to the *spongy parenchyma* with the characteristic square or quad-

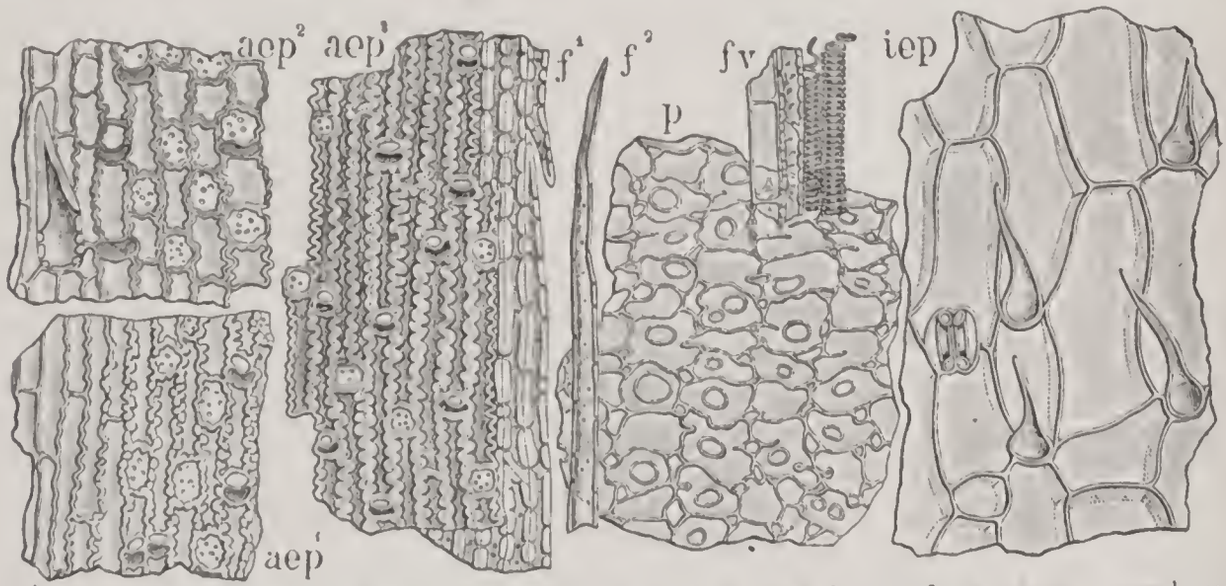


Fig. 107.—Barley. Elements of flowering glume in surface view. *aep*^{1} outer epiderm at thin margin midway between base and tip. *aep*^{2} outer epiderm at tip. Tissues over middle of dorsal side of grain: *aep*^{3} outer epiderm; *f*^{1} thick-walled fibers; *f*^{2} thin-walled fiber; *fv* fibro-vascular bundle; *p* spongy parenchyma; *iep* inner epiderm. ×160. (A.L.W.)

[1] Mikroskopie der Nahrungs- und Genussmittel. Berlin, 2 Aufl. 1905, p. 200.

[2] Landw. Vers.-Stat. 1898, **50**, 1.

rilateral cells as these are quite different from the hide-shaped cells of the corresponding layer of oats.

The *epidermal cells* on both the outer and the inner surface are of the general structure found in the chaff of the chaffy wheats, oats, and some other grasses. Stomata, abundant on oat glumes, are, however, lacking. Tschirch and Oesterle state that stomata are absent on the outer epiderm of both flowering glume and palet, and our examination of numerous samples confirms this; Vogl, however, not only describes stomata but pictures them. Quite possibly a modified form may occur, but the practical distinction between barley and oats in this regard still holds. At the edge of the flowering glume the wavy-walled elongated cells with twin and round cells pass into straight-walled elongated cells (aep^1) and at the tip into a tissue with short cells and short thick-walled hairs (aep^2).

The *sclerenchyma fibers* and the *spongy parenchyma* are lacking on the thin edges.

Palet.—This has the same general structure as the flowering glume. Rows of hairs such as form a saw edge on the keels of oat palet are absent.

Lodicules (Fig. 108).—The cells of the *epiderm* are thin-walled and characterless. The *hairs* that spring from among them are remarkable for their variety. The longest range up to 1300 μ or more and have thin walls, the lumen being several times their thickness. Some hairs not quite so long have thick walls and lumen with constrictions. Some of the medium sized thin-walled hairs have branches. Short forms with thick and thin walls, with and without branches, occur in considerable numbers.

Pericarp (Figs. 106, *F*; Fig. 109).—Cross sections give a rather vague idea of the layers since the inner epiderm of the chaff and that of the epicarp are not only united but the cells are more or less compressed, as are also those of the hypoderm. Surface preparations, obtained by scraping, are more instructive, all the layers but the spermoderm and perisperm being easily differentiated without special treatment.

FIG. 108.—Barley. Tip of lodicule with hairs. ×160. (A.L.W.)

The layers consist of (1) *epicarp* of elongated, polygonal, rather indistinctly beaded cells (epi^2), passing at the apex into non-beaded cells (epi^1) forming rosettes about the *hairs* (t^1 and t^2); (2) *hypoderm* (*hy*) of similar cells forming two or more layers; (3) double *cross-cell layer* (*tr*) of transversely elongated, isodiametric, non-beaded cells, side by side in rows; and (4) detached *tube cells* (*tu*) forming the endocarp.

Most of the *hairs* resemble wheat hairs with lumen narrower than the walls and ranging up to 300 μ in length; some, however, resemble rye hairs, the lumen being broader than the walls. Hairs of the thin-walled type up to over 650 μ may be found.

The *cross cells* are characteristic because they are not beaded or so indistinctly beaded as to require treatment with sodium hydroxide to

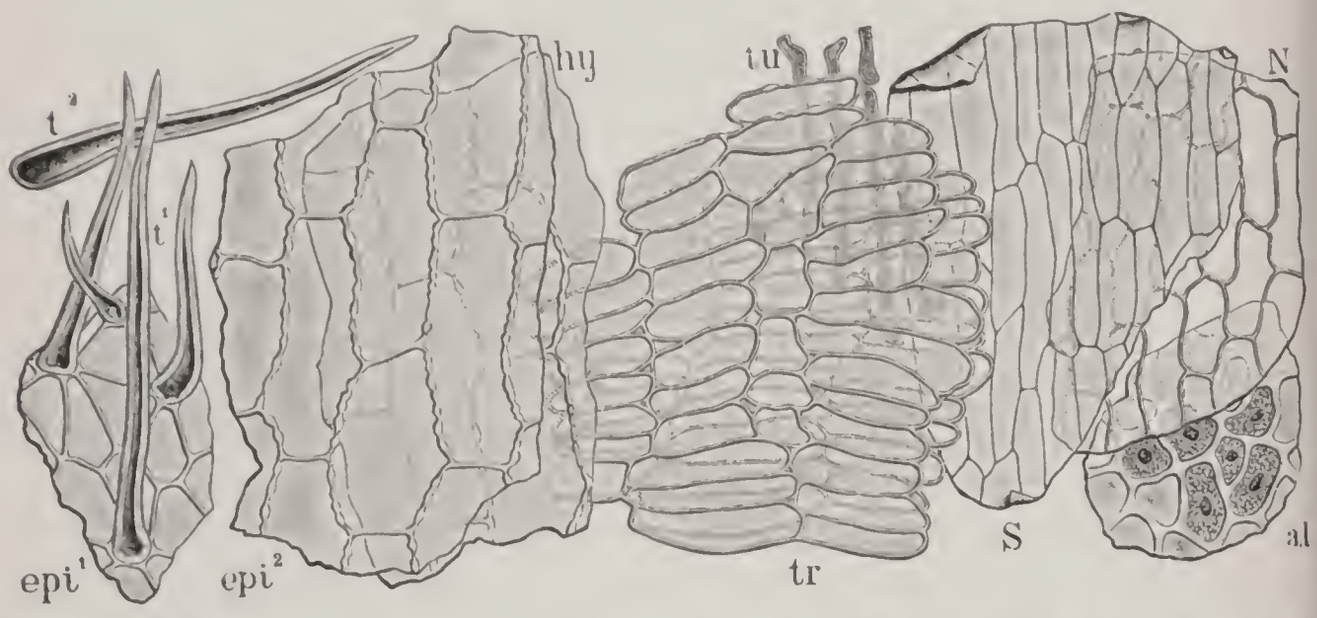


FIG. 109.—Barley. Bran coats in surface view. epi^1 epicarp at apex of kernel with t^1 and t^2 hairs. Layers on middle of dorsal side: epi^2 epicarp; *hy* hypoderm; *tr* double layer of cross cells; *tu* tube cells; *S* spermoderm; *N* perisperm; *al* aleurone cells of endosperm. ×160. (A.L.W.)

bring out this character; furthermore, they are in two layers over the greater part of the kernel. Intercellular spaces occur sparingly between the end walls, especially in the outer layer.

Spermoderm (Figs. 106 and 109, *S*).—In cross section the spermoderm appears as a colorless line; in surface view it is best differentiated by Moeller's method as follows: Soak a whole grain in water, remove the chaff and outer bran coats by scraping, boil the kernel thus partially decorticated with 1 per cent sodium hydroxide for a few minutes, scrape again, and mount the scrapings in chlorzinc iodine. The spermoderm stains yellow, the perisperm blue, and both show the cellular structure.

Thus obtained, the spermoderm is seen to form one layer of elongated

cells with delicate walls, arranged in various ways, sometimes in short rows side by side.

Statements by various authors that two spermoderm layers are present appear to be due to mistaking the perisperm for a spermoderm layer.

Perisperm (Figs. 106 and 109, *N*).—Obtained as described in the foregoing section, the cells are seen to be broader, shorter, and thicker-walled than the spermoderm cells. The walls are also more or less wavy. Without treatment the cells are not so clearly seen in surface view. In cross section the layer is distinguished from the spermoderm by its greater breadth, evident radial walls, and narrow lumen.

Endosperm (Figs. 106 *E*; 109).—The *aleurone cells* (*al*) differ from those of all other cereals in that they are two to four cells deep. Although this is a character best seen in cross section, it often happens that fragments of surface or powder mounts show this distinction.

The cells are also smaller than in wheat or rye, the average diameter being usually not much more than half that of wheat aleurone cells. Although the contents are usually pale yellow, in some varieties, according to Körnicke and Werner[1] and Benecke,[2] they may be blue.

The *starch cells* (*am*) contain *starch grains* smaller than those of wheat and still more noticeably smaller than those of rye, both of which they otherwise resemble. The largest grains seldom exceed 30 μ.

Embryo.—In microscopic as well as macroscopic structure the embryo is much like the wheat embryo. It may be studied in median longitudinal sections and cross sections beginning at the very base of the kernel, the latter being useful, if for no other reason, in determining the number of secondary radicles.

Chief Structural Characters.—Grain chaffy or naked, spindle-shaped, ribbed. Groove broad and shallow.

Outer epiderm of glume and palet without stomata and stiff hairs (both present in oats) but rachilla with stiff hairs and lodicules with soft hairs (both absent in oats). Spongy parenchyma rectangular (hide-shaped in oats). Cross cells without distinct beads, forming a double layer, and aleurone cells two to four cells thick (distinction from other common cereals). Starch grains lenticular, seldom over 30 μ.

MICROSCOPY OF BARLEY PRODUCTS.—Whole Barley is used for human food only in the roasted form as a coffee substitute. The characters, although altered by roasting, usually are sufficiently preserved to show their identity.

[1] Handbuch des Getreidebaues. Berlin, 1885.

[2] Landw. Vers.-Stat. 1889, **36**, 337.

Malt is sprouted and steamed whole barley from which the radicle has been removed. Except for the starch grains and radicles all the original elements are present.

Malt Sprouts, removed in the preparation of malt, are characterized by the *root hairs* on the epiderm. These are not like ordinary hairs but are long papillæ formed on the cells without cell division. They may be compared to nails, the sprout being the shank and the cell proper the head.

Flour prepared from barley, although wholesome and popular in certain remote regions, is little used in times of peace by the multitude. Lenticular starch grains up to 30 μ, fragments of the double cross-cell layer and aleurone layer, and hairs are the chief elements.

Grits and **Pearl Barley** differ little from flour in their constituents. The shallow groove favors decortication.

Brewers' and Distillers' Grains contain all the elements of barley except the starch grains and the radicle of the germ, together with the cellular elements of such other cereals as may have been used.

Maize is recognized chiefly by the elongated beaded cells of the thick epicarp and hypoderm, rice by the wavy-walled transversely elongated epicarp cells, rye by the cross cells with indistinctly beaded and swollen end walls, and wheat by the cross cells with distinct beads and thin end walls. The chaff of oats is distinguished by the hide-shaped spongy parenchyma cells; the grain proper, by the long slim hairs narrowed at the base.

CHEMICAL COMPOSITION.—The purposes for which barley is grown—namely, for the fermentation industries and for animal feeding whether directly or in the form of brewery and distillery residues—have led to lines of investigation other than those followed for the bread cereals, wheat and rye.

Early analyses of American barley include 2 made in the United States Department of Agriculture [1] and 8 reported in the Census of 1880,[2] showing a range of 8.59 to 15.73 per cent of protein. In 1893, 32 analyses were made of barley exhibited at the World's Fair, Chicago,[3] but it was not until ten years later that extensive investigations were undertaken, one by Chamberlain[4] to determine the feeding value and one by Le Clerc and Wahl[5] under an appropriation of Congress with the view of improving the quality, particularly for malting.

[1] Rep. 1878, p. 148.
[2] **3**, 421.
[3] U. S. Dept. Agr., Bur. Chem. Bul. **45**, p. 14.
[4] U. S. Dept. Agr., Bur. Chem. 1909, Bul. **120.**
[5] Ibid. 1909, Bul. **124.**

The average of Chamberlain's analyses and the 32 World's Fair samples are tabulated below:

COMPOSITION OF AMERICAN AND FOREIGN BARLEY (CHAMBERLAIN ET AL.)
(Results on dry basis)

	Samples	Water in in air-dry samples	Protein (N × 6.25)	Fat	N-f.ext.	Fiber	Ash
		%	%	%	%	%	%
United States and Canada (1893):	32						
Aver.		10.80	11.98	2.39	78.35	4.54	2.74
Foreign (1906):	8						
Aver.		9.38	12.52	2.06	78.03	4.53	2.81
United States (1906):	123						
Min.		8.14	8.31	0.37	70.48	3.94	2.33
Max.		13.28	19.94	2.51	82.13	8.99	3.63
Aver.		9.32	13.39	1.87	76.05	5.64	3.04
Hull-less (1906):	5						
Aver.		9.07	16.09	1.90	77.01	2.64	2.36

Accepting the above figures as representative, the average protein content of American barley increased nearly 1.5 per cent from 1893 to 1906, outstripping that of foreign barley. This improvement is explained by Chamberlain as due to the effort to secure a high protein content whether in the feeding class, to which the barleys of his investigation strictly belong, or in brewery barleys, whereas in Europe the aim is to increase the starch at the expense of protein.

The table below shows the average amounts of the organic constituents obtained in the Bureau of Chemistry in the barleys of Le Clerc and Wahl's report. Certain other physical data obtained in Wahl's laboratory, of interest chiefly to the fermentation industries, are given in the bulletin. A summary of determinations of ash and of some of the inorganic constituents is given under the head of Mineral Contsituents.

It may seem at a glance that these brewing barleys are not of such high protein content as those considered in Chamberlain's bulletin. The Bay Brewing and Utah Winter barleys are particularly low in protein and high in starch.

Le Clerc and Wahl also report average analyses of barleys in terms

AVERAGE OF ORGANIC CONSTITUENTS OF AMERICAN BARLEY (LE CLERC AND WAHL)
(Results on dry basis)

	Samples	Water in air-dry sample	Total protein	Soluble protein	Soluble noncoagulable protein	Soluble coagulable protein	Fat	Lecithans as lecithin *	Starch	Pentosans	Fiber
		%	%	%	%	%	%	%	%	%	%
Six-rowed:											
Ordinary †	84	8.71	11.86	2.22	1.46	0.65	2.02	0.52	58.87	9.64	5.71
Bay Brewing	18	8.39	10.73	1.67	1.35	0.45	2.03	0.55	58.32	9.82	6.58
Utah Winter	9	8.46	9.96	1.83	1.39	0.44	1.98	0.53	59.86	8.96	5.79
Two-rowed:											
Ordinary	18	8.92	11.64	2.05	1.53	0.61	2.01	0.52	59.08	8.41	5.23
Hull-less	1	8.73	12.06	2.27	1.76	0.51	2.17	0.57	65.47	8.38	5.62

* Phosphorus soluble in alcohol and ether × 11.37.
† Oderbrucker and Manchurian.

of hulls, bran, embryo, and endosperm, as determined by dissections carried out by Young:

	Samples	Hulls	Bran	Embryo	Endosperm
		%	%	%	%
Six-rowed:					
Ordinary	84	12.06	11.69	2.44	72.69
Bay Brewing	18	14.38	11.08	2.44	70.20
Utah Winter	9	12.89	10.87	1.95	72.80
Two-rowed:					
Ordinary	18	10.39	12.31	2.51	72.58
Hull-less	1	.....	18.23	2.90	79.39

Mealy and Horny Barley.—The texture of the grain has been regarded as a rough guide to composition, but Just and Heine [1] have shown that although it is true that the horny grains of the same variety are as a rule higher in protein than the mealy, it is not true that all horny varieties are protein-rich and all mealy varieties are the reverse.

This may be readily understood if the nature of the cell contents is considered. The cementing material, forming the matrix for the starch, consists largely of proteins. When this is present to such an extent that the protein-starch complex completely fills the cells, the appearance will be horny regardless of the ratio of protein to starch. Hence a horny kernel will have a high protein content if the starch content is low, but a relatively low protein content if the starch content is high. The same

[1] Landw. Vers.-Stat. 1889, **36**, 269.

may be said of a mealy grain, the difference being that in this case more or less air is present in the cell.

High and Low Protein Barley.—Whether or not associated with a horny condition, high-protein barley is highly valued for feeding, but opinions differ as to its suitability for malting.

Formerly only a low protein content was considered favorable for brewing, but in the United States and to some extent in Europe a reasonably high protein content is not now regarded as detrimental and may be advantageous. High-protein barley is well adapted for distillers' malt.

An excellent review of the literature on this subject and much information based on their own experiments are given in Le Clerc and Wahl's Chemical Studies of American Barley and Malts.[1]

Changes in Composition during Storage.—According to Takahashi and Shirahama,[2] hordein and glutelin, especially the former, increase during storage at the expense of water-soluble compounds or insoluble proteins.

Pearl Barley and Barley Flour.—The composition of these products is shown by the following figures taken from Atwater and Bryant's Compilation:[3]

Composition of Pearl Barley and Barley Flour

	Samples	Water	Protein	Fat	N-f. ext.*	Fiber	Ash
		%	%	%	%	%	%
Pearl barley:	3						
Min.		9.8	7.0	0.7	77.3	0.3†	0.6
Max.		12.9	10.1	1.5	78.1	0.3†	1.6
Aver.		**11.5**	**8.5**	**1.1**	**77.8**	**0.3†**	**1.1**
Barley flour:	3						
Min.		9.9	9.0	1.5	70.4	5.9	1.6
Max.		13.6	12.7	3.2	74.5	7.0	3.8
Aver.		**11.9**	**10.5**	**2.2**	**72.8**	**6.5**	**2.6**

* Includes fiber.
† 1 sample.

Proteins.—Kreusler,[4] following Ritthausen's general system, classifies the proteins of the barley kernel as *gluten-casein*, *gluten-fibrin*, *mucedin*, and *albumin*.

[1] U. S. Dept. Agr., Bur. Chem. 1909, Bul. **124.**
[2] Bul. Agr. Chem. Soc. Japan 1928, **4**, 55.
[3] U. S. Dep. Agr., Off. Exp. Sta. 1899, Bul. **28**, rev.
[4] Ritthausen: Die Eiweisskörper, etc., p. 104.

Osborne[1] adopted a different nomenclature consistent with that of the wheat proteins as follows: (1) *protein insoluble* in water, salt solution, and alcohol, but soluble in dilute alkali and acid, (2) *hordein*, soluble in 75 per cent alcohol, the mucedin of Ritthausen and Kreusler, (3) *edestin* (globulin), soluble in salt solution, (4) *leucosin* (albumin), and (5) *proteose*. He was unable to separate the "insoluble protein," that is insoluble in salt solution but soluble in dilute alkali, since known as *glutelin*, in a state of purity. The percentages of the different proteins in the barley kernel containing 1.83 per cent of total nitrogen and 10.75 per cent of total protein (calculated on the basis of 17 per cent of nitrogen) as estimated by Osborne follow:

1. Leucosin (soluble in water)	0.30
2. Edestin (soluble in salt solution) and proteose	1.95
3. Hordein (soluble in alcohol)	4.00
4. "Insoluble protein" by difference	4.50
	10.75

The only results available on the specific rotation of hordein are those of Lindet and Ammann,[2] who consider that this protein is made up of two proteins with different rotatory power. Their results, not being comparable with those of other workers on other gliadins, are not here given.

Two *glutelins*, α and β, have been shown by Csonka and Jones[3] to be present in the barley kernel. α-glutelin is precipitated from a 0.2 per cent sodium hydroxide solution on addition of ammonium sulphate to 1 to 2 per cent saturation; β-glutelin, on subsequent addition to 18 per cent saturation. The isoelectric point of α-glutelin is (pH) 6.4; its specific rotation at 20° as found by Csonka, Horn, and Jones[4] is -111.1.

Proteins of Naked Barley.—The alcohol-soluble proteins of naked barley have been shown by Takahashi and Shirahama[5] to contain two fractions, one soluble and the other insoluble in absolute alcohol. The former was constant in composition during two seasons; the latter was not.

Ultimate Composition of Barley Proteins.—Osborne's analyses bring out the correspondence of the albumin (leucosin) and globulin (edestin) of wheat and barley, also the lack of correspondence of hordein with

[1] J. Am. Chem. Soc. 1895, **17**, 539.
[2] Bul. soc. chim. 1907, **1**, 968.
[3] J. Biol. Chem. 1929, **82**, 17.
[4] Ibid. 1930, **89**, 267.
[5] J. Fac. Agr. Hokkaido Imp. Univ. 1927, **21**, 43.

the gliadin of wheat, the carbon content being somewhat higher in the former. In view of the similarity of hordein with both wheat and rye gliadin in some other respects, it seems possible that further investigation may explain the discrepancy in the carbon content.

Ultimate Composition of Barley Proteins (Osborne)

	Leucosin	Edestin	Hordein
	%	%	%
Carbon	52.81	50.88	54.29
Hydrogen	6.78	6.65	6.80
Nitrogen	16.62	18.10	17.21
Sulphur	1.47	.....	0.83
Oxygen	22.32	24.37 *	20.87
	100.00	100.00	100.00

* Includes Sulpeur.

The ultimate composition of α-glutelin, calculated free of water and 0.41 per cent of ash, as found by Csonka, and Jones [1] follows:

	%
Carbon	54.31
Hydrogen	6.94
Nitrogen	16.16
Sulphur	1.21
Oxygen	21.38
	100.00

Amino Acids of Barley Proteins.—Hordein, the gliadin or prolamine of barley, was the only protein isolated by Osborne in sufficient amount and of sufficient purity to warrant a study of its cleavage products.

Both Kleinschmitt [2] and Osborne and Clapp [3] have subjected hordein to hydrolysis and determined the kind and approximate amount of the amino acids thus liberated with on the whole remarkably agreeing results considering the difficulties involved, except that the former obtained nearly 8 per cent more proline than the latter. In both instances, however, cystine was not determined and lysine was reported as being absent.

[1] Loc. cit.

[2] Z. physiol. Chem. 1907, **54**, 110.

[3] Am. J. Physiol. 1907, **19**, 117.

Johns and Finks[1] who have employed Van Slyke's method for determining the nitrogen distribution, found arginine 2.88, cystine 1.18, lysine 0.89, and histidine 2.27 per cent.

The following are Kleinschmitt's percentages with Osborne and Clapp's results for proline and Johns and Finks' results for cystine, lysine, and histidine substituted:

	%
Glycocoll	0.0
Alanine	1.4
Valine	1.4
Leucine	7.0
Serine	0.1
Cystine	1.2
Aspartic acid	1.3
Glutamic acid	41.3
Tyrosine	4.0
Phenylalanine	5.5
Proline	13.7
Tryptophane	+
Arginine	3.2
Lysine	0.9
Histidine	2.3
Ammonia	4.4
	87.7

Osborne regards wheat and rye gliadins as probably identical but hordein as a distinct individual. Judging from the hydrolysis products, it would appear that the distinction of hordein from wheat gliadin is not greater than that of rye gliadin from wheat gliadin. The ultimate analyses of gliadin and hordein show appreciable differences, particularly in the carbon content, that must be given due weight.

Unfortunately the proteins of barley, as well as rye, were extracted from the ground whole kernels and not from carefully separated morphological parts as was found desirable in Osborne's later wheat investigations.

Jones, Gersdorff, and Moeller[2] obtained in 2 preparations of barley hordein the following:

	Cystine	Tryptophane
	%	%
I	1.55	1.05
II	1.47	0.44

[1] J. Biol. Chem. 1919, **38**, 63.

[2] J. Biol. Chem. 1924, **62**, 183.

Cystine and basic amino acids of α-glutelin were present in the following amounts, as determined by Csonka and Jones:[1] cystine 3.10, arginine 5.59, lysine 2.88, and histidine 1.09 per cent.

Nitrogen Distribution of α-Glutelin.—Csonka and Jones,[1] in addition to the percentages of basic amino acids given above, report the nitrogen distribution by Van Slyke's method with the following results, expressed as percentages of the total nitrogen:

	%
Humin N	2.52
Cystine N	2.24
Arginine N	11.13
Lysine N	3.41
Histidine N	1.84
Amino acids in filtrate	52.79
Non-amino acids in filtrate	9.15
Amide N	16.09
	99.17

Nitrogen Distribution in Barley.—Applying Van Slyke's method for the determination of the nitrogen distribution, Grindley and Slater [2] and Nollau [3] obtained respectively the following percentages which in a number of instances are far from concordant: amide nitrogen 15.16 and 16.19; humin nitrogen 8.79 and 2.87; cystine nitrogen 1.26 and 4.38; arginine nitrogen 9.46 and 8.65; histidine nitrogen 3.64 and 6.70; lysine nitrogen 2.19 and 0.00; mono-amino nitrogen 45.81 and 44.16; non-amino nitrogen 13.84 and 18.37; total nitrogen 100.15 and 101.32.

Fat (Ether Extract). *Physical and Chemical Values.*—Stellwaag [4] and Wallerstein[5] have analyzed the ether extract of barley with the following results:

	Stellwaag	Wallerstein
Free fatty acids	13.62%	8.39%
Neutral fat	77.78%	83.85%
Lecithin	4.24%	3.06%
Unsaponifiable residue	6.08%	4.70%
Saponification number	181.7	182.1
Iodine number	.....	114.6
Reichert-Meissl number	.....	0.031

[1] Loc. cit.

[2] J. Am. Chem. Soc. 1915, **37**, 2762.

[3] J. Biol. Chem. 1915, **21**, 611.

[4] Landw. Vers.-Stat. 1890, **37**, 135.

[5] Forschungsb. 1896, **3**, 372.

Dietrich[1] found that the ether extract had a specific gravity of 0.9145 (15.5°) and showed a butyrorefractometer reading of 65°. The iodine number varied between 106 and 107 and the percentage of lecithin was 3.2.

Calculated to the barley, the lecithin found by Dietrich in the ether extract would be less than 0.07 per cent, but it is well known that only a part is extracted from the grain by ether.

Täufel and Rusch[2] have determined the physical and chemical values of the fat of barley and of malt, germ, and brewers' grains from barley as shown herewith:

VALUES OF FAT OF BARLEY AND PRODUCTS (TÄUFEL AND RUSCH)

	Sp. gr. 15°/4°	Saponification No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Ester No.	Total fatty acids	Acid No.	Unsaponifiable matter
							%		%
Barley	0.9547	188.4	113.5	0.87	0.35	159.4	80.6	29.0	5.4
Malt	0.9608	176.6	116.9	.....	.....	148.7	79.9	27.9	6.1
Germ *	0.9795	141.5	99.4	.....	.....	72.9	63.3	68.6	26.0
Germ †	0.9840	145.3	95.3	3.98	0.41	57.2	64.5	88.1	23.2
Brewers' grains	0.9659	172.3	104.9	1.71	0.32	132.0	79.6	40.3	7.7

* "Putzereikeim." † "Sankeim."

The last-named authors separated the solid and liquid fatty acids by the Twitchell method, calculated the stearic and palmitic acids from the neutralization values and the oleic and linolic acids from

COMPOSITION OF FAT OF BARLEY AND PRODUCTS (TÄUFEL AND RUSCH)

	Stearic acid	Palmitic acid	Oleic acid	Linolic acid	Linolenic acid	Unsaponifiable matter
	%	%	%	%	%	%
Barley	2.6	7.4	26.5	43.7	0.44	5.4
Malt	5.1	8.2	16.4	49.4	0.82	6.1
Germ *	9.6	4.0	18.1	30.1	0.49	26.0
Germ †	9.0	4.2	25.3	25.5	0.48	23.2
Brewers' grains	8.7	7.6	19.1	43.8	0.47	7.7

* "Putzereikeim." † "Sankeim."

[1] Landw. Vers.-Stat. 1901, **56**, 207.

[2] Z. Unters. Lebensm. 1929, **57**, 422.

the iodine numbers, and determined the linolic acid by the hexabromide method.

Carbohydrates.—Barley does not appear to differ materially from wheat and rye in its carbohydrates. It contains *sucrose*, *raffinose*, and under some conditions *invert sugar*. Owing to the high diastatic power of barley, *maltose* and *dextrose*, which occur sparingly if at all in the sound ripe kernels, are readily formed when the proper conditions of moisture and heat are attained.

The *pentosans* of which Le Clerc and Wahl found 8.38 to 9.82 per cent, appear to be *araban* and *xylan*. The *galactoxylan* of Lintner and Düll occurs in barley as well as wheat.

Some of the changes in malting are noted under Malt.

Phosphorus-Organic Compounds. *Lecithin.*—A direct determination by Dietrich,[1] boiling repeatedly with alcohol, yielded 0.24 per cent which, calculated to the dry substance, is equivalent to 0.29 per cent. Schulze[2] found as high as 0.47 per cent calculated to the dry substance, and Le Clerc and Wahl, as shown in a foregoing table, found 0.52 to 0.57 per cent.

Phytin.—Determinations in two varieties of air-dry barley by Averill and King[3] yielded 1.07 and 1.19 per cent of phytin ($C_6H_{18}O_{24}P_6$).

Freshly prepared barley flour, according to Minkovska,[4] contains phosphoric acid in the following forms and percentage amounts: inorganic 0.076, phytic 0.59, and various other organic combinations 0.20.

Nucleic Acid.—See Wheat.

Porphyrin.—Fischer and Schwerdtel[5] obtained porphyrin from barley as well as other cereals. This may exist in the grain in the form of porphyratin as claimed by Schumm and Mertens (see Oats).

Enzymes.—See Enzymes under Chemical Composition of Malt and By-Products.

Mineral Constituents.—The content of ash and some of the ash constituents as reported by Le Clerc and Wahl,[6] calculated to the air-dry grain, are summarized in the table on the following page.

The above figures, calculated to percentages of the ash, are in accord with the average of Wolff's complete ash analyses as follows: potash 20.92, soda 2.39, lime 2.64, magnesia 8.83, ferric oxide 1.19, phosphoric acid 35.10, sulphuric acid, 1.80, chlorine 1.02, and silica 25.91.

[1] Loc. cit.
[2] Landw. Vers.-Stat. 1897, **49**, 203.
[3] J. Am. Chem. Soc. 1926, **48**, 724.
[4] Bul. acad. Polonaise 1926, B, 1007.
[5] Z. physiol. Chem. 1926, **159**, 120.
[6] Loc. cit.

Analyses of American Barley Ash (Le Clerc and Wahl)

(Results in percentages of the dry grain)

	Samples	K_2O	CaO	MgO	P_2O_5	Total S	Ash
		%	%	%	%	%	%
Six-rowed:							
Ordinary	84	0.70	0.08	0.22	1.06	0.182	2.98
Bay Brewing	18	0.70	0.07	0.23	1.00	0.154	2.98
Utah Winter	9	0.64	0.09	0.21	0.93	0.168	2.87
Two-rowed:							
Ordinary	18	0.72	0.08	0.22	1.05	0.173	2.88
Hull-less	1	0.66	0.07	0.19	1.03	0.159	2.24

Minor Mineral Constituents. *Iron.*—Barley 40, pearl barley 12 mg. per kilo (Häusermann).[1] Barley flour 10 mg. per kilo (Sherman).[1]

Aluminum.—Barley 6.7 mg. per kilo, dry basis (Bertrand and Lévy).[2]

Manganese.—Four-rowed barley 11.4 mg. per kilo, dry basis (Wester).[3] Barley 8.33 mg. per kilo, air dry basis (Quartaroli);[4] 12 to 20 mg. per kilo, dry basis (Davidson)[5].

Copper.—Barley 6.5 mg. per kilo, air-dry basis (Guerithault);[6] 1.61 mg. per kilo (Quartaroli).[4]

Zinc.—Barley, Chevalier, Pacific Coast 26.7, barley malt 11 mg. per kilo, air-dry basis (Birckner).[7] Whole seed 18 mg. per kilo, air-dry basis (Bertrand and Benzon).[8]

Ash of Awns.—The highly silicified awns of barley contain a large percentage of ash, amounting, according to Harlan and Pope,[9] in some cases to over 30 per cent. The rachis of awnless varieties or awned varieties from which the awn has been removed is brittle owing to diversion of ash to this part.

CHEMICAL COMPOSITION OF MALT AND BY-PRODUCTS.—During the steeping, germinating, and drying stages of the process of malting, the grain loses solid matter by conversion into carbon dioxide (respiration) and undergoes marked changes in the carbohydrates, proteins, and fats. According to Browne,[10] the enzyme *amylase*, acting on

[1] Sherman's Compilation, U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. 185.
[2] Compt. rend. 1931, **192**, 525.
[3] Biochem. Z. 1921, **118**, 158.
[4] Ann. chim. appl. 1928, **18**, 47.
[5] Cereal Chem. 1929, **6**, 128.
[6] Compt. rend. 1920, **171**, 196.
[7] J. Biol. Chem. 1919, **38**, 191.
[8] Bul. soc. hyg. aliment. 1928, **16**, 457.
[9] J. Agr. Res. 1921, **22**, 433.
[10] Handbook of Sugar Analysis. New York, 1912, p. 684.

the starch, produces maltose, and *glucase*, acting in turn on the maltose, produces glucose. In addition to the products of hydrolysis, sucrose is formed by synthesis from reducing sugars. O'Sullivan[1] found in two experiments that during malting the sucrose increased from 0.9 and 1.39 to 4.50 and 4.50 per cent, maltose was formed to the extent of 1.2 and 1.98 per cent, glucose increased from 1.1 and 0.62 to 3.1 and 1.57 per cent, and fructose was formed to the extent of 0.2 and 0.71 per cent.

Numerous analyses of malt are reported by Le Clerc and Wahl[2] and compared with the analyses of the barley from which they were made. Only the average percentage losses and gains during malting of 43 samples need here be given as follows: total protein −12.0, soluble protein +72.5, soluble non-coagulable protein +104.0, soluble coagulable protein +13.0, fat −7.7, lecithin +34.3, starch −28.0, reducing sugars as invert +400.0, cane sugar +71.0, fiber −8.4, pentosans −1.6, ash −20.7, potash −48.2, lime −22.3, magnesia −17.6, phosphoric acid −12.7, sulphur +9.0, hulls −8.5, bran −37.0, embryo +78.7, and endosperm −10.2.

The extreme percentages of the carbohydrates in the 43 samples of malt calculated to the dry basis follow: starch 41.22 to 53.45, reducing sugars as invert 3.76 to 11.04, sucrose 2.35 to 5.81, and pentosans 8.32 to 11.88.

Proteins of Malt.—An extensive study of the changes that take place in the proteins of barley during malting was made by Osborne and Campbell.[3] They found that both the hordein and the edestin disappear and a new alcohol-soluble protein (*bynin*) and a new salt-soluble protein (*bynedestin*), both richer in carbon but poorer in nitrogen, take their places. The albumin (*leucosin*) apparently remains unchanged and increases in amount. The percentages of the proteins in the malt examined follow:

Protein insoluble in salt solution and alcohol	3.80
Bynin, soluble in dilute alcohol	1.25
Bynedestin, leucosin, and proteoses:	
Coagulable	1.50
Uncoagulable	1.29
	7.84

Hordenin, a product of protein decomposition, according to Torquati,[4] is not present in normal barley but is found during sprouting.

[1] J. Chem. Soc. 1886, p. 58.

[2] Loc. cit.

[3] Connecticut Agr. Exp. Sta. Rep. 1895, p. 239.

[4] Arch. farm. sper. 1911, **10**, 62.

The content is highest during the first four days and then decreases up to twenty-five days when none is present.

Enzymes.—Malt was known by the ancients to possess saccharifying power and was one of the first vegetable products studied with reference to its enzymes. Germinated barley, as stated by Maestrini,[1] contains amylase and invertase which are soluble in water, lipase and protease which act in an emulsion but are not present after filtering, also catalase and oxidase but no maltase (see below), lactase, or rennase. The possible presence of two amylases is noted below, also the presence of an enzyme acting on pentosans and of two or more proteolytic enzymes acting on proteins and peptides. All these and other enzymes doubtless occur in other malted cereals.

Protease.—Giesen [2] found in barley 0.26 per cent, calculated as trypsin, the optimum temperature being 30 to 40° C. According to Wahl,[3] lactic acid produced in the mash through the agency of bacteria is an important factor in the activation of the proteases of yeast. He believes that the acid liberates the enzyme from its combination with some base. Lundin[4] gives as the optimum for the peptic protease in malt *p*H 3.7 to 4.3, and in green malt ±3.2, and for the tryptic protease in green malt and malt germ 6.3, which figures are somewhat less than in the case of yeast proteases. Two proteolytic enzymes are present in green malt according to Mill and Linderstrøm-Lang,[5] one, a protease with optimum *p*H of 4.3 at 40° when acting on edestin, the other, a peptidase with optimum *p*H of 7.6 to 7.9 at 40° when acting on leucylglycine. The latter is the more unstable and is greatly inhibited by phosphates.

Peptidase.—Hopkins [6] notes the presence in green malt of a peptidase eluted in an alkaline medium and a protease eluted in an acid medium. Both show a maximum adsorption at about *p*H 4.7. Sato [7] concludes from the hydrolytic velocity of peptides that two peptidases are present in green malt, not one, as stated by other authors.

Amylase.—Malt amylase has been the subject of many investigations. The work of Osborne,[8] Sherman and Gettler,[9] Sherman and Schlesinger,[10]

[1] Atti. accad. Lincei 1919, **28**, II, 393, 456; 1919, **28**, II, 509.
[2] Inaug. Dis. Bern. 1909.
[3] Eighth Int. Cong. Appl. Chem. 1912, **14**, 215.
[4] Biochem. Z. 1922, **131**, 193.
[5] Compt. rend. trav. lab. Carlsberg 1929, **17**, 1.
[6] Biochem. J. 1929, **23**, 1022.
[7] Compt. rend. trav. lab. Carlsberg 1931, **19**, 1.
[8] J. Am. Chem. Soc. 1895, **17**, 593.
[9] Ibid. 1913, **35**, 1790.
[10] Ibid. 1913, **35**, 1617; 1915, **37**, 1305.

and others indicates that the enzyme is a protein or related thereto. Using aluminum hydroxide as the adsorption medium, following in general Willstätter's method, Lüers and Sellner [1] so purified malt amylase as to increase the protein content from 42.99 to 74.4 per cent and reduce the carbohydrates from 43.56 to 28.07 per cent.

On the other hand, Fricke and Kaja [2] consider that a protein is not the active substance in amylase, basing their belief on the failure of tryptic digestion or precipitation with uranyl salts, if not added in excess of the protein, to influence the diastatic power, although traces of uranyl salts were strongly inhibitory.

Biochemists are divided as to whether there are two amylolytic enzymes in malt, one producing maltose, the other dextrinose, or whether there is only one producing both. Lecoq [3] and Windisch [4] are among the recent authors who believe that two amylases are present. Syniewski [5] considers that there are in barley two amylases, α and β, the first giving with iodine violet, red, and brown colors or none at all, the second the usual blue color. According to Polak and Tychowski, [6] the α-amylase exists in the barley but the β form appears during malting, although it does not act until the starch is brought into solution. Considering starch as made up of amylopectin and amylose, the former, after autoclaving, is hydrolyzed by β-amylase to dextrin I, the latter by α-amylase to maltose and by β-amylase to dextrin II which in turn is hydrolyzed to maltose by α-amylase. Edfeldt, Nordh, and Swaetichin [7] are of the opinion that there are two amylases, not an amylase and a dextrinase, in malt.

In experiments by Fricke and Kaja, [8] malt amylase was not changed in its dextrinizing and saccharifying power on purification by electrodialysis and electroösmosis, thus refuting the theory that two distinct enzymes bring about these changes. Evidence secured by Sabalitschka and Schulze, [9] notably the uniformity of the dextrinizing and saccharifying power of solutions treated with various adsorption media, indicates that one enzyme brings about the formation of both soluble carbohydrates. Sabalitschka and Weidlich [10] corroborate this view.

Maltase.—According to Wierzchowski, [11] maltase is present in small amount in barley. Ling and Nanji [12] found it in barley before sprouting,

[1] Wochschr. Brau. 1925, **42**, 97.
[2] Ber. 1924, **57**, 313.
[3] Compt. rend. 1924, **91**, 924.
[4] Wochschr. Brau. 1925, **42**, 276.
[5] Biochem. Z. 1925, **158**, 87.
[6] Ibid. 1929, **214**, 216.
[7] Ibid. 1930, **223**, 478.
[8] Loc. cit.
[9] Fermentforsch. 1925, **8**, 428.
[10] Biochem. Z. 1929, **215**, 267.
[11] Ibid. 1913, **57**, 125.
[12] Biochem. J. 1923, **17**, 593.

also in green and kiln-dried malt. A maltase isolated by Pringsheim and Leibowitz[1] has its optimum activity at *p*H 4.5 to 5.

Pentosase.—Determinations of pentosans by Baker and Hulton[2] in barley and malt showed a distinct gain during sprouting at the expense of non-pentosans. The increase of pentosans in the embryo and the decrease in the endosperm point to the presence of an enzyme, appropriately named pentosase, that acts on pentosans, converting them into soluble forms, thus permitting translocation.

Catalase.—Matsuyama[3] gives as the optimum *p*H 7 to 8 at 20° in 0.05 N hydrogen peroxide. The optimum for other strengths of hydrogen peroxide and other temperatures are also given. Charmandaryan and Tyutyunnikova[4] show that both cations and anions activate the catylase, the order beginning with the most effective for cations being Na, NH_4, Mg, Ca, Mn, Zn, and for anions Cl, NO_3, SO_4.

Maltsters', Brewers', and Distillers' By-Products.—Although various cereals, as well as potatoes and saccharine products, furnish the raw material for the fermentation industries, malt is an essential ingredient when the saccharification of starch is involved, and for this reason treatment under barley appears logical.

Brewers' and distillers' grains, also malt sprouts, are fed to cattle in the moist condition, when obtainable, before fermentation sets in. Modern practice, however, usually necessitates drying.

The composition of the dried by-products is well illustrated by a summary of analyses made by Kellogg in connection with the enforcement of the Pennsylvania feed inspection law given on the next page.[5]

Malt Sprouts.—The composition of malt sprouts is shown in the following table. The product is rich in protein but, being a further development of the radicle, contains no starch. Other carbohydrates and nitrogen-free substances are present.

Yoshimura[6] has demonstrated the presence of maltose and invert sugar but, counter to the statement of Grüss, was unable to find sucrose. He also isolated choline, betaine, and histidine.

Brewers' Grains.—Sixty-three lots of dried brewers' grains examined at the Marburg Experiment Station contained, according to Dietrich:[7] water 2.4 to 13.6, aver. **8.7**; protein (N × 6.25) 17.4 to 30.0, aver. **22.7**; fat 3.9 to 10.1, aver. **7.6**; nitrogen-free extract 31.2 to 50.5,

[1] Biochem. Z. 1925, **161**, 456.
[2] J. Chem. Soc. 1917, **111**, 121.
[3] Ibid. 1929, **213**, 122.
[4] Ibid. 1930, **222**, 272.
[5] Pennsylvania Dept. Agr., Bur. Chem. 1913, Bul. **249**.
[6] Biochem. Z. 1911, **31**, 221.
[7] Landw. Vers.-Stat. 1901, **56**, 207.

Composition of Maltsters', Brewers', and Distillers' Offal (Kellogg)

	Samples	Water	Protein	Fat	Fiber
		%	%	%	%
Malt sprouts:	9				
Min		5.61	23.00	1.48	9.97
Max		9.01	32.53	3.53	14.82
Aver		**7.06**	**27.17**	**2.40**	**11.89**
Dried brewers' grains:					
Largely barley	40				
Min		4.07	20.81	5.66	10.25
Max		8.99	36.10	8.25	16.17
Aver		**7.08**	**28.19**	**7.07**	**12.93**
Dried distillers' grains:					
Largely corn	23				
Min		5.00	25.31	8.30	7.95
Max		10.02	35.88	13.97	13.20
Aver		**6.73**	**29.28**	**11.70**	**10.82**
Largely rye	3				
Min		4.97	18.25	4.53	10.25
Max		12.11	27.56	9.43	12.04
Aver		**8.03**	**22.10**	**7.40**	**11.36**

aver. **42.0**; fiber 10.6 to 24.9, aver. **15.1**; and ash 2.2 to 5.6, aver. **3.9** per cent.

From 70 to 100 per cent of the total *protein* existed as true proteins and from 33.1 to 91.2 per cent, dissolved in artificial digestive solutions, the lowest solubilities being due to overheating in drying.

In the *fat* extracted with ether from commercial and laboratory dried grains, respectively, Dietrich obtained: free fatty acids calculated as oleic 32.7 and 26.5 per cent; lecithin 6.3 and 6.2 per cent; neutral fat (in the first) 56.2 per cent; unsaponifiable matter (in the first) 4.8 per cent; iodine number 93.6 and 107; unsaponifiable matter 195 and 182 per cent; butyrorefractometer reading at 40° C. 66 and 64.5. The total lecithin in the dried grains was 1.48 and 1.89 per cent.

Starch (gelatinized) and *sugars* occur only in small amount in brewers' grains; *pentosans* vary from 20 to 30 per cent in the air-dried material.

The *ash* in 6 samples of dried brewers' grains examined at the Marburg Experiment Station, according to Dietrich, ranged from 2.6 to 5.17 per cent. Analyses of the ash showed: potash 2.1 to 4.44, soda trace to 1.10, lime 8.42 to 16.8, magnesia 8.66 to 13.16, ferric oxide 2.1 to 4.43, manganic oxide (1 sample) 1.5, phosphoric acid 32.32 to 40.51,

silica 25.33 to 39.42, and sulphuric acid 0.96 to 1.51 per cent, chlorine trace.

Distillers' Grains.—The dried residues from the manufacture of alcohol and distilled liquors in Europe show a wide range in composition owing to the variety of cereals, as well as potatoes, used for mashing. Eighteen analyses of dried distillers' grains from cereal mash (Brennereitreber), reported by Dietrich [1] show: water 2.5 to 10.0, protein (N × 6.25) 14.4 to 27.7, fat 5.1 to 16.1, nitrogen-free extract 34.5 to 52.8, fiber 10.8 to 18.0, and ash 1.6 to 4.5 per cent.

The averages of analyses of 9 lots of dried rye grains (Branntweinschlempen) and of 23 lots of dried maize grains from different countries, also reported by Dietrich,[2] are: water 10.8 and 8.1, protein 22.5 and 27.7, fat 5.4 and 12.9, nitrogen-free extract 46.7 and 36.3, fiber 8.8 and 9.3, and ash 5.8 and 5.7 per cent.

SIX-ROWED BARLEY

Hordeum sativum Jess. var. *hexastichon* (L.) Hackel = *H. hexastichon* L.

Fr. Orge à six côtés. Sp. Cebada caballar. It. Orzo. Ger. Sechszeilige Gerste.

Although six-rowed or round barley was probably derived from a two-rowed form, this development must have taken place in prehistoric times, as the only barley of the Egyptians and Greeks and the common barley of the lake dwellers was six-rowed.

In barleys of this type, unlike two-rowed varieties, all three spikelets of each group are fertile, which fact, taken in conjunction with the equal spacing of the spikelets on opposite sides of the rachis, explains the six rows. Although the two side spikelets are fertile they do not have the vigor of the central one and the grains are smaller. This is in harmony with the theory that the six-rowed varieties originated from the two-rowed, the grain from the flowers once sterile never reaching quite the development of the central grain.

MACROSCOPIC STRUCTURE.—There are bearded and hooded groups and under each group chaffy or common and naked or hull-less varieties.

Atterberg [3] describes two distinct groups of the bearded chaffy type, one (*H. hexastichon spurium*) like four-rowed barley with the side kernels twisted, the other (*H. hexastichon verum*) with a cross wrinkle at the

[1] Loc. cit.

[2] Ibid. 1902, **56**, 321.

[3] Landw. Vers.-Stat. 1889, **36**, 23.

base of both central and side kernels and a swelling each side of the wrinkle of the central kernel.

MICROSCOPIC STRUCTURE.—There are no well-established distinctions from two- or four-rowed varieties, comparing chaffy with chaffy, naked with naked, and hooded with hooded.

FOUR-ROWED BARLEY

Hordeum sativum Jess. var. *vulgare* (L.) Hackel = *H. vulgare* L.

Fr. Orge. Sp. Cebada comun. It. Orzo. Ger. Vierzeilige Gerste.

Since this type differs from the six-rowed type merely in that the adjoining side spikelets of opposite groups are crowded into the same row, some botanists prefer the name "square six-rowed" to "four-rowed."

There appear to be no marked macroscopic distinctions of four-rowed barley from six-rowed barley of Atterberg's "*spurium*" group, or microscopic differences other than those based on adherence of chaff or presence of a hood.

NUTS OF THE OAK FAMILY

(*Fagaceæ*)

Included under the term cup nuts are the starchy fruits of the oaks (*Quercus*) and chestnuts (*Castanea*) and the oily nuts of the beeches (*Fagus*). Since acorns and chestnuts yield flour and starch comparable in composition with the corresponding cereal products, they are included in this chapter.

COMPARATIVE MACROSCOPIC STRUCTURE.—The trees are monœcious, the *staminate flowers* occurring in catkins, the *pistillate flowers* singly (*Quercus*) or in small groups (*Castanea*). Characteristic of the fruit is the involucre or cupule, now regarded as an extraneous growth, which forms the cup of acorns and the bur of chestnuts.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—Both genera agree in having: (1) *epicarp*, hairy at the tip, with dark contents, (2) dense *hypoderm* of stone cells, (3) *mesocarp* of parenchyma, and (4) hairy *endocarp*.

In acorns a thin-walled *crystal layer* lies between the epicarp and the hypoderm, and in both chestnuts and acorns crystal rosettes occur in the mesocarp.

Spermoderm.—Both genera have a hairy *outer epiderm*. The hairs are often long and for the most part thin-walled, although thick-walled forms occur in the chestnut.

Cotyledons.—*Starch* is the chief constituent.

COMPARATIVE CHEMICAL COMPOSITION.—As regards the nutrients, the kernels of both the chestnut and the acorn differ in composition from wheat and other naked cereals in that they contain more soluble carbohydrates, only about half of the nitrogen-free extract being starch. The sweet taste is in accord with the high percentage of sugars found on analysis. Acorns contain more or less of a bitter substance which, although present in small amount, renders them unsuited for food, at least in their natural condition. A comparison of ash analyses of the chestnut with those of wheat shows a higher percentage of sulphuric acid.

CHESTNUT

Castanea spp.

Fr. Marron. Sp. Castaña. It. Marrone. Ger. Kastanie.

Large nuts are produced by the European chestnut (*C. sativa* Mill. = *C. vesca* Gaertn.) and two oriental species (*C. crenata* S. et Z. and *C. mollissima* Blume). The lordly American species (*C. dentata* Borkh. = *C. americana* Raf. = *C. sativa* var. *americana* Michx.), which in recent years largely has disappeared owing to the ravages of the oriental chestnut-bark disease, yields smaller nuts but of excellent flavor, and the chinquapins (*C. pumila* Mill and *C. alnifolia* Nutt), both low-growing species, yield still smaller but easily gathered nuts.

Chestnuts are eaten roasted throughout Europe. Shelled they are valuable for poultry dressing and in other ways. Chestnut flour is used in Italy for various desserts.

MACROSCOPIC STRUCTURE.—European and Japanese chestnuts reach 3 cm. or more in width; American chestnuts, only about half that dimension. The densely spiny *bur* opens at maturity disclosing usually two or more brown *nuts*—in the chinquapin only one—which are broad at the base, tapering to the soft, elongated, hairy tip. Both the inner surface of the tough pericarp and the outer surface of the thin, soft spermoderm are downy. The *seed* is anatropous. The cotyledons are longitudinally furrowed.

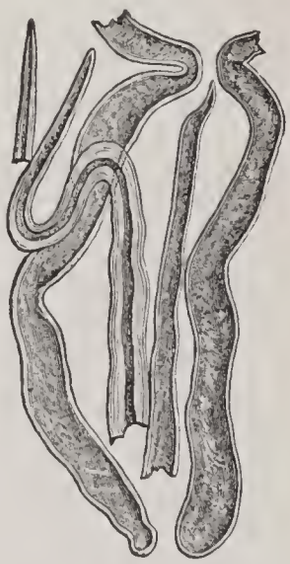


FIG. 110.—Chestnut. Hairs from spermoderm. ×160. (A.L.W.)

MICROSCOPIC STRUCTURE.—The **Pericarp** consists of (1) *epicarp* of thin-walled, usually polygonal cells with dark contents, (2) *hypoderm* of several layers of radially elongated stone cells, largest in the outer layer, (3) *mesocarp* of longitudinally elongated cells, with swollen walls, containing crystal clusters, and vascular bundles, and (4) densely hairy *endocarp*.

The *outer hypoderm* cells in tangential section have deeply sinuous walls. Commonly the *hairs* are thin-walled, but thick-walled forms also occur. They vary up to 2 mm. or more in length.

Beneath the scar and at the tip the structure is different from that described.

Spermoderm.—The *outer epiderm* is conspicuous because of its hairs (Fig. 110). The middle and inner layers are inconspicuous.

Cotyledons.—The outer layer consists of small, somewhat radially elongated, thin-walled *aleurone cells* containing protein and oil but no

starch. Large polygonal *starch cells* make up the remainder of the tissues.

The *starch grains* (Plate I, Fig. 10) are pear-shaped, ellipsoidal, and of various grotesque forms, reaching 24 μ in length. The hilum is in the broad end. Clefts are sometimes present. Twins and triplets occur here and there.

Chief Structural Characters.—Nut broadest at base, tapering to elongated soft tip. Epicarp tough, brown, hairy at tip, with scar at base. Spermoderm thin, hairy. Cotyledons bulky.

Epicarp of polygonal cells; hypoderm of radially arranged stone cells with sinuous outline in tangential section; mesocarp swollen; endocarp and spermoderm with thin- and thick-walled hairs. Cotyledons with outer aleurone layer and inner starch cells. Starch grains grotesque, up to 24 μ, with eccentric hilum.

CHEMICAL COMPOSITION.—Frear [1] has reported the results of 8 analyses of chestnuts, namely: 2 of Spanish chestnuts, 2 of the native

Composition of Chestnut Kernel (Frear)

(Chemical constituents in percentages of dry matter)

	Spanish	Spanish	Native	Native	Paragon	Numbo	Solebury	Moon's
	%	%	%	%	%	%	%	%
Shell	21.51	25.25	23.24	22.87	23.94	11.49	15.32	14.32
Kernel:								
Water	6.63	5.43	34.45	4.82	6.53	42.25	29.17	41.66
Dry matter	71.86	69.32	42.31	72.31	69.53	46.26	55.51	44.02
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Protein:								
True proteins	8.38	9.28	11.84	10.53	10.91	8.68	8.07	9.63
Amides, etc.	1.23	1.68	0.39	1.67	1.23	1.90	1.44	1.11
	9.61	10.96	12.23	12.20	12.14	10.58	9.51	10.74
Fat	7.11	9.58	16.42	16.08	9.76	11.46	11.67	11.00
N-f. ext.:								
Glucose	5.19	12.63	14.06	3.50	9.13	6.76	13.78	6.71
Dextrin	17.45	8.23	7.63	12.01	11.05	14.40	15.02	14.74
Starch	24.24	23.87	16.81	50.65	32.15	20.49	34.27	33.95
Other substances	30.84	29.02	26.63		19.97	29.39	9.73	16.55
	77.72	73.75	65.13	66.16	72.39	71.04	72.80	71.95
Fiber	2.53	2.84	3.62	2.84	2.68	3.74	3.51	3.26
Ash	3.03	2.87	2.60	2.72	3.12	3.18	2.51	3.05
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Pennsylvania Agr. Exp. Sta. Rep. 1891, Bul. 16, 12.

American species, 3 (Paragon, Numbo, and Solebury) of American seedlings from European stock, and 1 (Moon's) of a seedling from American stock. The analyses include figures for true proteins ("albuminoids") and amides, also for the different carbohydrates.

The high percentages of dextrin, the low percentages of starch, and the nature of the "other substances" need explanation.

Analyses of 2 samples of Italian chestnuts were made by Colby[1] in connection with a study of California-grown nuts. Physical analyses follow:

	I	II
	%	%
Husk	43	35
Shell	9	10
Kernel	48	55
	100	100

Determination of the percentage of nitrogen in each part of the two samples gave respectively: husk 0.50 and 0.22, shell 0.76 and 0.26, and kernel 1.06 and 0.65. The average water content of the kernel was 53.2 per cent and the average percentages of the constituents in the water-free kernel were: protein 11.55, fat 4.22, nitrogen-free extract 78.45, fiber 3.10, and ash 1.68 per cent.

French chestnuts and Virginia-grown native chestnuts have been analyzed by Robb.[2] The composition of the kernels, which amounted to 88.81 and 82.01 per cent respectively of the whole husked nut, is shown in the table which follows:

Composition of Chestnut Kernel (Robb)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
French	52.24	3.12	1.56	40.56	1.37	1.15
Virginian	33.45	10.19	10.20	42.35	1.93	1.88

An analysis of the edible part of the chestnut, constituting 82.6 per

[1] California Agr. Exp. Sta. 1896, Bul. **113.**

[2] Virginia Chemists' Club Proc. **2,** 13.

cent of the whole nut, has been made by Baker and Hulton.[1] The kernel when shelled contained 59.86 per cent of moisture but was dried at 55° C. before grinding for analysis. The composition of the dried kernel follows:

Composition of Chestnut Kernel (Baker and Hulton)

	%
Water	4.70
Protein	7.44
Fat	2.90
N-f. ext.	80.00
Fiber	2.28
Ash	2.68
Reducing sugar or dextrose	5.36
Sucrose	9.00
Starch (taka-diastase)	41.08
Starch (Lintner)	50.60
Pentosans	3.06
Cold water extract	22.08

Chestnut Flour is an important food in Italy. Its composition and food value in comparison with cereal flours have been studied by Leoncini and Manetti.[2] Determination of the usual proximate constituents was made in 8 samples, representing the product of different sections of Italy, and of the individual carbohydrates in 7 of the samples.

Composition of Chestnut Flour (Leoncini and Manetti)

	Water	Protein	Fat	N-f. ext.	Reducing sugars	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Min.	10.75	7.43	3.30	66.58	2.72	20.51	34.04	2.65	2.02
Max.	16.70	8.56	3.90	72.17	3.16	30.59	48.46	2.95	3.02
Aver.	**13.96**	**8.02**	**3.54**	**69.94**	**2.88**	**26.72**	**39.98**	**2.80**	**2.54**

Fat.—The only available data are by Robb,[3] who states that the oil of the native species is liquid at 0° C., has a refractive index of 1.4693 (temperature ?), and a saponification number of 207.5.

Carbohydrates.—See analyses above by Frear, Baker and Hulton, and by Leoncini and Manetti.

The percentages of the individual carbohydrates found by Robb[3]

[1] Analyst 1918, **43**, 32.

[2] Staz. sper. agr. ital. 1911, **44**, 66, 113.

[3] Loc. cit.

in the kernels of samples described above, calculated to the dry basis, follow:

CARBOHYDRATES OF CHESTNUT KERNEL (ROBB)

	French	Virginian
	%	%
Reducing sugars	6.26	2.39
Sucrose	6.89	15.55
Dextrin	0.37	0.51
Starch	63.60	35.70
Pentosans	4.87	5.44
Waxes, gums, resins	1.48	2.18
Undetermined	1.63	2.19
	85.10	63.96

A study of the results by the different analysts shows that often half or more of the carbohydrate matter in the nut consists of substances other than starch and that the amount of sucrose exceeds that of reducing sugar. It is difficult to reconcile some of the results reported except as due to faulty methods.

Mineral Constituents.—The average composition by Colby[1] of the ash of the parts of the 2 samples of Italian chestnuts described above, also of the nut, husked but not shelled, follows:

ANALYSES OF CHESTNUT ASH (COLBY)

	Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
Husk	1.16	32.23	0.99	17.83	10.15	3.93	0.58	9.61	5.05	18.69	0.90
Shell	0.81	29.02	3.92	27.52	14.51	0.47	0.24	21.10	2.08	0.42	0.67
Kernel	0.79	48.67	1.20	4.63	8.05	0.41	0.16	23.55	12.81	0.18	0.34
Nut	0.83	45.07	1.70	8.82	9.24	0.43	0.18	23.10	10.84	0.22	0.40

* In fresh material.

Minor Mineral Constituents. *Manganese.*—Pericarp and spermoderm 29.3, cotyledons 16.1, embryo other than cotyledons 15.2 mg. per kilo, dry basis (Quartaroli).[2]

Copper.—Pericarp and spermoderm 3.2, cotyledons 9.8, embryo other than cotyledons 68.4 mg. per kilo, dry basis (Quartaroli).[2]

Zinc.—Kernel 4.1 mg. per kilo, dry basis (Bertrand and Benzon).[3]

Iodine.—None (Winterstein).[4]

[1] Loc. cit.

[2] Ann. chim. appl. 1928, **18**, 47.

[3] Bul. soc. hyg. aliment. 1928, **16**, 457.

[4] Z. physiol. Chem. 1918, **104**, 54.

ACORNS

Quercus spp.

Fr. Gland. Sp. Bellota. It. Ghianda. Ger. Eichel

A vast amount of starchy food goes to waste in acorns because of their bitter taste. Some species and some trees of the bitter species produce acorns of sufficient palatability to be relished by farm animals. Roasted acorns have been used in Europe as a coffee substitute.

MACROSCOPIC STRUCTURE.—A cup (cupule), covering more or less of the acorn according to the species, corresponds to the bur of a chestnut. Since only one acorn is borne in the cup it is cylindrical, tapering abruptly at the top to a short beak.

MICROSCOPIC STRUCTURE.—Mitlacher[1] describes fully the tissues of cupule, pericarp, and spermodern of *Q. sessiliflora* Salisb.; other authors have confined their attention chiefly to the seed.

Except for the presence of a layer of thin-walled cells, each containing a single crystal, between the epicarp and the hypoderm, the structure is analogous to that of the chestnut, differing chiefly in the following details: (1) the *epicarp* cells are for the most part quadrilateral, (2) the cells of the *inner mesocarp* are elongated, forming a loose tissue separated by elongated intercellular cavities, and (3) the *starch grains* have well-marked elongated hilums.

CHEMICAL COMPOSITION.—Acorns, although similar to chaffy cereals in composition, like horse-chestnuts, contain bitter and astringent substances that render them unpalatable. They may, however, be used in limited amount for feeding swine and some other farm animals. Goats

Composition of Acorn Kernel

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Cranfield	13.86	7.88	4.57	67.82	3.63	2.24
Baker and Hulton:						
I	3.32	7.50	4.70	79.50*	2.28	2.70
II	1.45	6.65	5.00	82.45†	2.20	2.25

* Starch (taka-diastase) 43.4, (Lintner) 55.70; reducing sugar as dextrose 8.18; sucrose 0.10 per cent.

† Starch (taka-diastase) 44.3, (Lintner) 57.10; reducing sugar as dextrose 4.90; sucrose 1.90, pentosans 3.20 per cent.

[1] Z. allg. oesterr. Apoth.-Ver. 1901, **39**, 1.

eat certain kinds with relish. When fresh they contain as much as 50 per cent or more of water.

Cranfield,[1] who recommends acorns as food for poultry, has analyzed the kernels of partially dried nuts containing 20 per cent of shell and 80 per cent of kernel; Baker and Hulton[2] have analyzed the kernels of two samples dried at 55° C. These analyses appear on the foregoing page.

[1] J. Bd. Agr. 1918, **25**, 573.
[2] Analyst 1917, **42**, 351.

BUCKWHEATS AND WEED SEEDS OF THE BUCKWHEAT FAMILY

(*Polygonaceæ*)

This family, although far removed from the *Gramineæ* in the scheme of classification, for our purpose should be considered in connection with the cereals because buckwheat, its most important representative, ranks with the true cereals in our diet. So far as the proximate constituents ordinarily determined are concerned, buckwheat flour cannot be distinguished by its analysis from flour of the true cereals.

Only members of the genus *Fagopyrum*—the true buckwheats—are cultivated, the species of *Polygonum* and *Rumex* described below being weed seeds, although of excellent nutritive value.

Microscopically, buckwheat, as well as the other members of the family, has starch similar to that of oats and rice (although lacking oval aggregates) and to that of the millet group, also an aleurone layer hardly distinguishable from that found in the members of the cereal group. When the pericarp and spermoderm are taken into account, the gross and microscopic structures of the true cereal and buckwheat groups are widely dissimilar.

COMPARATIVE MACROSCOPIC STRUCTURE.—The apetalous flowers have in our common species an inconspicuous *calyx*, more or less lobed or parted, which covers the fruit at maturity. The one-celled, one-seeded dry *fruit* (achene) is usually triangular or flattened, brown or black. A thin spermoderm covers the *seed*, the larger part of which is floury endosperm. The *embryo* in buckwheat has broad, thin, folded cotyledons embedded in the endosperm. In black bindweed and dock the narrow *cotyledons* adjoin the spermoderm in one angle and on one side respectively. Freed from the calyx, the *kernels* of buckwheat are dull gray or dark brown, of black bindweed, deep dull black, of smartweed, lustrous, black, and of dock, lustrous, medium brown. All the foregoing are always triangular except the smartweeds, which may be either flattened or triangular.

COMPARATIVE MICROSCOPIC STRUCTURE.—Striated papillæ characterize the *calyx* of buckwheat and black bindweed; they are absent on dock.

The *epicarp* of common buckwheat has spiral-reticulated markings which are absent or inconspicuous on the epicarp of Tartary buckwheat. Black bindweed has a sinuous-walled, much-thickened and convoluted epicarp with cuticular warts; the warts are absent on the epicarp of smartweeds and dock, which are otherwise similar. Buckwheats alone of the group have a *hypoderm* of sclerenchyma fibers.

The *outer epidermal* cells of the spermoderm in all the species described below have wavy walls and are arranged end to end in rows. In dock, these cells are of enormous size. The *middle layer* of the spermoderm is of spongy parenchyma, more or less modified, the individual cells in black bindweed and smartweeds being vermiform, detached, and transversely arranged.

In all the species, the *aleurone cells*, of the cereal type, are practically the same. Characteristic of the *starch grains* are their rounded polygonal form, medium size (seldom up to 18 μ), and frequent grouping into rod-like aggregates.

COMPARATIVE CHEMICAL COMPOSITION.—Comparison of the average of proximate analyses of buckwheat and black bindweed—data on other members of the group are meager—with that of wheat shows a slightly lower content of protein, due chiefly to the higher content of fiber. In milling, not only the hulls, which contain the bulk of the fiber, but also the embryo are removed, hence the flour, although low in fiber, is also relatively low in protein. Buckwheat flour may, however, contain as much protein as flour from certain grades of soft wheat, hence no sweeping conclusions can be reached.

Studies of the proteins of buckwheat show that it contains a globulin but no prolamine, the absence of the latter distinguishing it from most of the common cereals other than rice.

COMMON BUCKWHEAT

Fagopyrum esculentum Mönch. = *Polygonum Fagopyrum* L.

Fr. Sarrasin. Sp. Sarraceno. It. Grano saraceno. Ger. Buchweizen.

In agriculture and commerce, buckwheat, although the fruit of a dicotyledonous plant, is classed with the cereals for the reason that it is a bread grain. Structurally and chemically the endosperm resembles the cereals in that it has a non-starchy aleurone layer and a starchy interior, but the structure of other parts and the external appearance are very different.

Common buckwheat, as well as two other economic species mentioned by De Candolle, Tartary buckwheat (*F. tartaricum* Gærtn.) and notch-

seeded buckwheat (*F. emarginatum* Meissn.), is a native of central Asia. Its cultivation even in this region does not extend back more than a few centuries.

MACROSCOPIC STRUCTURE (Fig. 111).—The sharply three-angled or three-keeled, pointed dry *fruit* (achene) in common varieties is 4 to 6 mm. long, in the Japanese variety 6 to 9 mm. long. The color is various shades of brown or gray or streaked with both. The pinnately arranged striations proceed diagonally from the midrib on each face to the angles. A portion of the calyx often remains attached to the base of the fruit. The entire *calyx* is petal-like, white, except at

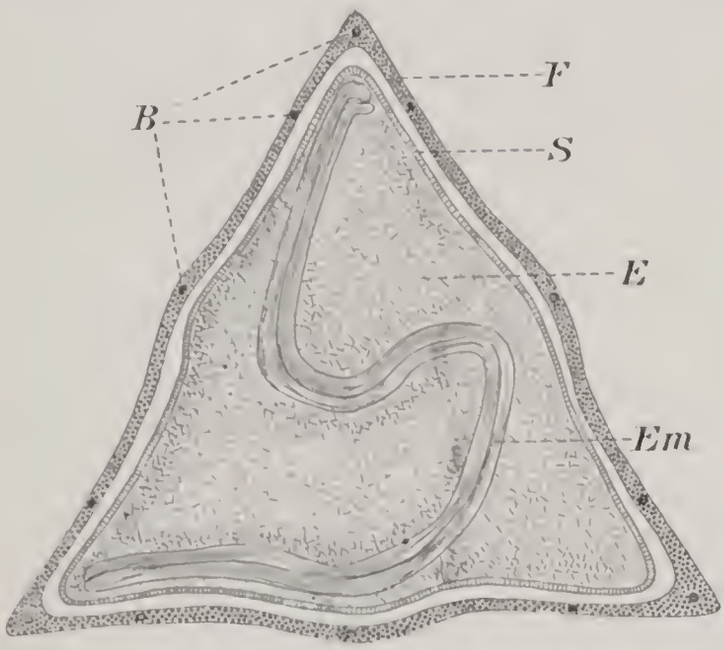


Fig. 111.

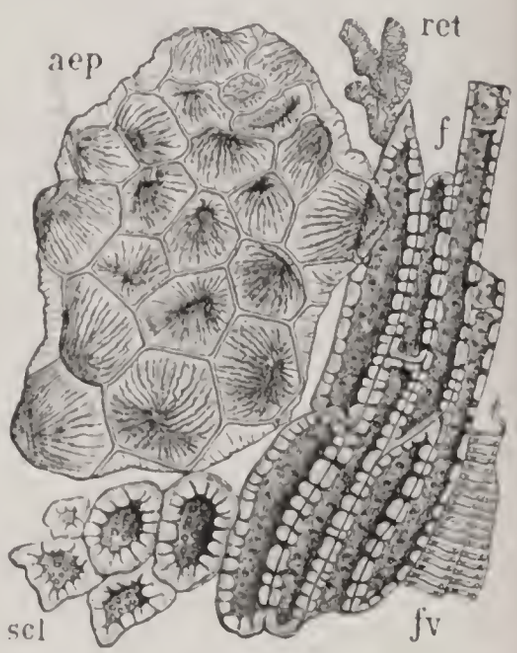


Fig. 112.

Fig. 111.—Common Buckwheat. Kernel in cross section. *F* pericarp with *B* bundles; *S* spermoderm; *E* endosperm; *Em* embryo. ×16. (A.L.W.)

Fig. 112.—Common Buckwheat. Elements from base of calyx in surface view. *aep* outer epiderm with papillæ and stoma; *scl* stone cells; *f* fibers and elongated stone cells; *fv* spiral vessels from bundle; *ret* reticulated cells. ×160. (A.L.W.)

the base where it is green, five-parted, and somewhat shorter than the fruit.

Unlike that of the true cereals, the leathery *pericarp* is not attached to the seed. Twelve main fibro-vascular *bundles* run longitudinally through the pericarp, one in each angle, one in the center of each side, and one about one-third the distance from each angle to the center of each side. The orthotropous *seed* is covered with a thin, greenish-yellow or light brown spermoderm. The pure white *endosperm* forms the bulk of the seed. Within it is embedded the *embryo* with its two thin but broad *cotyledons* so folded as to form in cross section a double curve or S.

MICROSCOPIC STRUCTURE.—Harz [1] found the microscopic structure of this species, *F. pyramidatum* H., and *F. emarginatum* Meissn. to be the same. He considers that what is described here as endosperm is perisperm (see Cockle).

Calyx (Fig. 112).—The noteworthy tissues of the upper or white portion of the calyx, where the texture is thin and petal-like, are the two epiderms, both with papillæ. The cells of the *outer epiderm* (*aep*) in the basal portion are larger than in the upper portion, reaching 50 μ. The outer wall of each cell throughout both the outer and inner epidermal tissues is more or less elevated to form a *papilla* with wavy striations radiating from the center or tip. *Stomata* occur here and there.

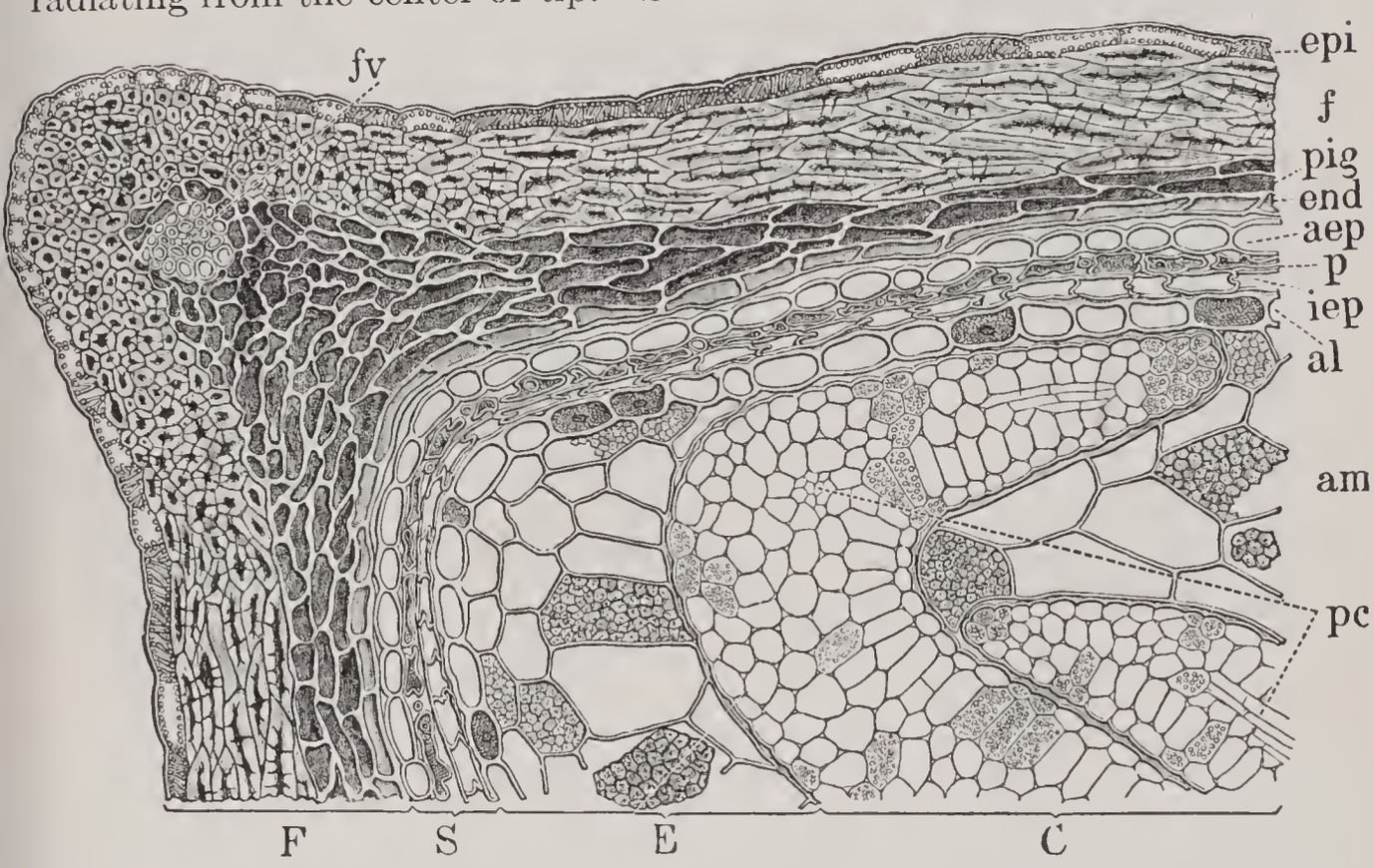


FIG. 113.—Common Buckwheat. Kernel in cross section through one of the angles. *F* pericarp: *epi* epicarp, *f* fiber layer, *pig* pigment parenchyma containing *fv* fibrovascular bundle, *end* endocarp. *S* spermoderm: *aep* outer epiderm, *p* spongy parenchyma, *iep* inner epiderm. *E* endosperm: *al* aleurone cells, *am* starch cells. *C* cotyledon with *pc* procambium bundle. ×160. (A.L.W.)

In the basal portion a *chlorophyl mesophyl* is well developed; in this ramify the *bundles* (*fv*) with robust spiral, annular, and reticulated vessels. Adjoining the bundles occur sclerenchyma elements, notably broad porous *fibers* (*f*), some pointed, others blunt, passing into *elongated stone cells*, *isodiametric stone cells* (*scl*), and *spiral-reticulated cells* (*ret*).

Pericarp (Fig. 113, *F*; Fig. 114).—Examination of cross and surface sections shows four layers as follows: (1) *epicarp* (*epi*) of elongated spiral-

[1] Samenkunde. Berlin, 1885, p. 1104.

reticulated cells arranged like the barbs of a feather on both sides of the central bundle of each face and longitudinally on the angles, (2) *fiber layer* (*f*), four to six cells thick, also arranged on the faces like the barbs of a feather and longitudinally in the angles, (3) *pigment layer* (*pig*) of parenchyma cells somewhat elongated tangentially with brown contents, two to three cells thick on the faces and thicker in the angles, and (4) *endocarp* (*end*) of large longitudinally elongated cells.

Through the pigment layer or between it and the fiber layer run the *fibro-vascular bundles* (*fv*) containing spiral vessels accompanied by sclerenchyma fibers and cells.

Spermoderm (Fig. 113, *S*; Figs. 115, 116, 117).—This forms a skin studied with difficulty in cross section. Surface preparations treated cautiously with sodium hydroxide show, by careful focusing, the three

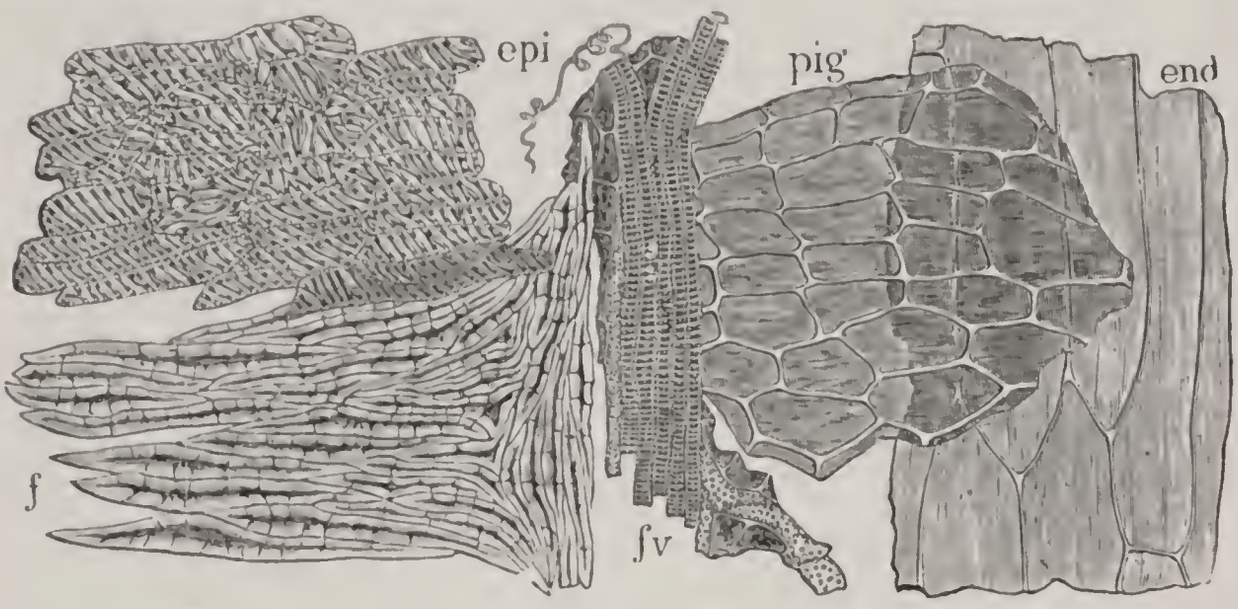


Fig. 114.—Common Buckwheat. Elements of pericarp (hulls) in surface view. *epi* epicarp; *f* fiber layer at angle; *fv* fibro-vascular bundle from one of the faces; *pig* pigment parenchyma; *end* endocarp. ×160. (A.L.W.)

layers, as well as the aleurone cells of the endosperm, one above the other, as follows: (1) *outer epiderm* (*aep*) of longitudinally elongated wavy-walled cells which become straight-walled near the base and finally at the base broader, (2) *spongy parenchyma* (*p*) containing green or brown chlorophyl grains, the cells being star-shaped on the body of the grain, rectangular near the base, and at the very base transversely elongated with few intercellular spaces, and (3) *inner epiderm* (*iep*) of longitudinally elongated cells with thin straight walls.

Endosperm (Fig. 113, *E*; Fig. 115).—The *aleurone cells* (*al*) both in cross section and surface view are like those of the cereals. Their tangential diameter reaches 50 μ or more.

The *starch cells* (*am*) are completely filled with polygonal or rounded *starch grains*, varying up to 18 μ but commonly less than 12 μ, which on

grinding often separate as a mass conforming to the shape of the cell. Oval or rounded aggregates, such as occur in rice, are not present, but two or more grains of various shapes and sizes are often united to form rod-shaped or branching aggregates, the consolidation, as noted by Vogl, being so complete as hardly to show the junctures. Grains smaller than the others or of hour-glass shape produce characteristic constrictions in the aggregates. The hilum is central and distinct. Polarization crosses are distinct but not brilliant.

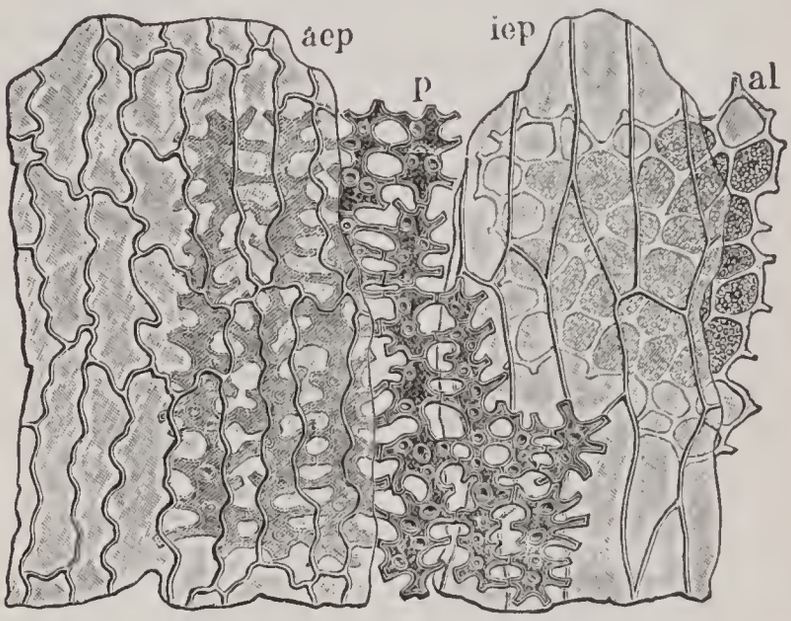


Fig. 115.—Common Buckwheat. Bran coats from center of one of the faces in surface view. Spermoderm: *aep* outer epiderm, *p* parenchyma, *iep* inner epiderm. *al* aleurone layer of endosperm. ×160. (A.L.W.)

Cotyledons (Fig. 113, *C*).—The cells are much smaller than in the endosperm and starch is absent. A layer of *palisade cells* lies beneath the *upper epiderm.*

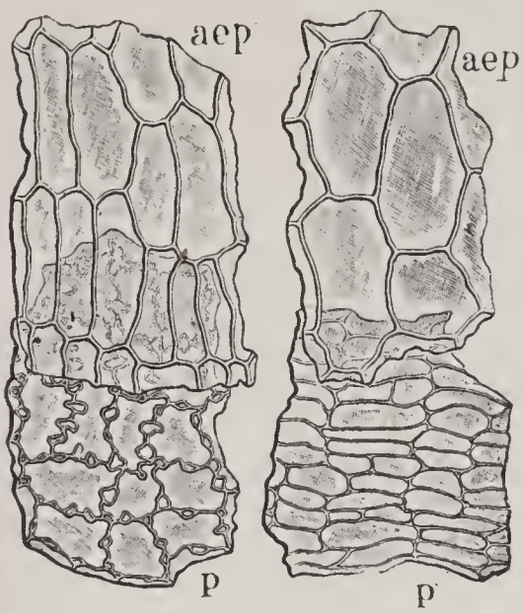


Fig. 116. Fig. 117.

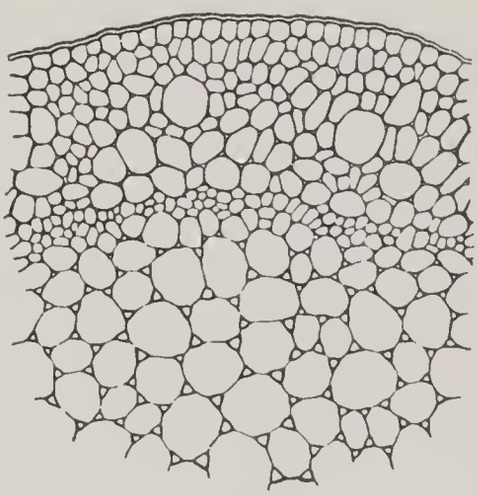


Fig. 118.

Fig. 116.—Common Buckwheat. Spermoderm near base in surface view showing *aep* outer epiderm and *p* spongy parenchyma. ×160. (A.L.W.)

Fig. 117.—Common Buckwheat. Spermoderm at base in surface view showing *aep* outer epiderm and *p* parenchyma. ×160. (A.L.W.)

Fig. 118.—Common Buckwheat. Radicle in cross section. ×160. (A.L.W.)

Through the ground *parenchyma* run in various directions *procambium bundles* (*pc*) with strikingly narrow elongated cells.

Radicle (Fig. 118).—Four distinct zones are evident in cross section: (1) *dermatogen* with thick outer walls, (2) *periderm* consisting of cells increasing in size from without inward, with noticeably larger cells occurring at intervals among the smaller outer cells, (3) *procambium* of very small cells, and (4) *core* of collenchymatously thickened cells. These are respectively the embryonic forms of the epiderm, cortex, bundle zone, and the pith. The third and fourth zones together form the *plerome cylinder*.

The larger cells in the cortex have crystal-like contents of different refraction from the surrounding tissues. Since these do not polarize nor stain with iodine they do not appear to be either calcium oxalate crystals or protein crystalloids.

Chief Structural Characters.—Grain triangular, dark, sometimes with part of calyx at base. Spermoderm thin. Embryo with broad but thin cotyledons in starchy endosperm.

Calyx with papillæ. Epicarp with spiral-reticulated cells; fibers thick-walled; pigment cells transversely elongated; endocarp cells longitudinally elongated. Spermoderm with wavy-walled, longitudinally elongated outer epiderm; middle tissues of spongy parenchyma; inner epiderm of elongated cells. Aleurone cells of cereal type; starch grains in masses and rod-shaped, often constricted, aggregates.

MICROSCOPY OF BUCKWHEAT PRODUCTS.—**Buckwheat Hulls,** at one time much used as an adulterant of black pepper, are detected by the characters named above.

Buckwheat Middlings or **Shorts,** the by-product of the manufacture of buckwheat flour, contains the greater part of the spermoderm, aleurone layer, and embryo. Often the three layers of the spermoderm and the aleurone layer may be seen, by careful focusing in the same fragment, after treating cautiously with sodium hydroxide.

Buckwheat Flour is ordinarily not so highly refined a product as wheat, rye, or even corn flour, owing partly to the nature of the grain and partly to the process. It contains in addition to starchy endosperm, often in masses, fragments of spermoderm which are of special service in identification. These are usually so numerous as to be evident on direct treatment on the slide with sodium hydroxide; if not, the special method of accumulation described under Wheat may be used. The rod-shaped starch aggregates are also characteristic. Flour made from black bindweed would have the same general microscopic characters as buckwheat flour, but the writers are not aware that it is made although the amount of the seed available would warrant its utilization in this way.

Of the cereals with small polygonal starch grains similar to those of buckwheat, rice, wild rice, oats, darnel, teff, and coracan may be dis-

tinguished by the presence of round or oval aggregates made up of a considerable number of grains and common, barnyard, and German millets, and the foxtails by the presence of a beaded network after treatment with sodium hydroxide. The large lenticular starch grains of wheat, rye, and barley and the large polygonal grains of maize and the sorghums furnish a ready means of distinction of flour made from these from buckwheat flour.

Griddlecake Mixtures of buckwheat flour with other flours are common. Formerly they were too often sold as pure buckwheat flour. The "grain" of buckwheat flour is peculiarly harsh and gritty when rubbed between the thumb and first finger, whereas wheat flour, a common admixture, is smooth. Special methods of detection are given under Wheat Flour.

Buckwheat Grits, said to be an important food in central Asia and Russia, is analogous to wheat and maize grits. Its microscopic characters are much the same as those of buckwheat flour.

CHEMICAL COMPOSITION.—Buckwheat grain has not been the subject of such extensive chemical studies as the common cereals of the grass family. The 8 analyses of buckwheat grown in New Hampshire, Massachusetts, Connecticut, New York, New Jersey, and Minnesota, made for the United States Census of 1880,[1] still serve well to illustrate the composition of this cereal.

Composition of Buckwheat (U. S. Census, 1880)

	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	10.89	8.58	2.15	62.63	7.77	1.57
Max.	14.82	11.00	2.39	65.37	9.37	2.34
Aver.	**12.62**	**10.02**	**2.24**	**64.43**	**8.67**	**2.02**

Buckwheat Flour.—Four analyses of old-fashioned flour, also made with one exception for the Census of 1880,[2] show the types of stone-ground flour then and now highly esteemed by New Englanders for griddle cakes.

Buckwheat By-products.—The offal of buckwheat milling consists primarily of (1) black *hulls* and (2) *middlings* made up of seed coat,

[1] III, p. 423.

[2] Loc. cit.

Composition of Buckwheat Flour (U. S. Census, 1880)

	Water	Protein (N×6.25)	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	12.78	4.18	0.65	71.10	0.21	0.65
Max.	17.63	8.13	1.79	79.37	0.52	1.26
Aver.	14.55	6.89	1.44	75.78	0.34	1.00

adhering endosperm, and embryo. The hulls have little feeding value but mixed with the middlings contribute roughage. The middlings is exceptionally rich in protein and fat which are derived chiefly from the aleurone layer and the embryo (germ) tissues. So-called *buckwheat feed*, a mixture of hulls and middlings, is a less concentrated cattle food.

Following are the averages of analyses of the by-products reported by Lindsey: [1]

Composition of Buckwheat By-Products (Lindsey)

	Samples	Water	Protein (N× 6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Buckwheat hulls	1	6.5	7.8	1.4	47.1	33.6	3.6
Buckwheat middlings	3	10.0	26.7	7.2	44.6	6.8	4.7
Buckwheat feed	2	10.0	15.9	4.1	44.8	22.0	3.2

The hulls in some instances have less than 3 per cent of protein and over 40 per cent of fiber, whereas the middlings may have over 30 per cent of protein and over 8 per cent of fat.

Proteins.—Ritthausen [2] prepared from aqueous and from alkaline extracts respectively 2.60 and 3.05 per cent of proteins to which he gave the general name *gluten-casein*, although they were quiet different from the gluten-casein of true cereals. The total of 5.65 per cent of proteins found by Ritthausen represents only part of that present in the kernel.

Johns and Chernoff [3] were unable to find more than a trace of protein soluble in 70 per cent alcohol, but did succeed in extracting, with 5 to 10

[1] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[2] Die Eiweisskörpen, etc. Bonn, 1872.

[3] J. Biol. Chem. 1918, **34**, 439.

per cent salt solution, *globulin* representing about 20 per cent of the total protein. They experienced difficulties in making the preparations on account of gums which gave the extracts a slimy consistency.

The *Ultimate Composition* of the gluten-casein according to Ritthausen is:

	%
Carbon	50.16
Hydrogen	6.80
Nitrogen	17.43
Sulphur	1.51
Oxygen	24.10
	100.00

Amino Acids of Buckwheat Proteins.—As determined by Johns and Chernoff,[1] the amino acids of the globulin are:

	%
Cystine	1.00
Arginine	12.97
Lysine	7.9
Histidine	0.59
	22.46

The high amount of basic amino acids, particularly lysine, as compared with that in wheat, is noteworthy.

Jones, Gersdorff, and Moeller [2] obtained in buckwheat globulin: cystine 2.47 and tryptophane 2.69 per cent.

Determinations by Kiesel [3] of the hexone bases in two preparations of *glutelin* extracted by 0.1 per cent sodium hydroxide gave the following results.

	I	II
	%	%
Arginine	6.71	7.55
Lysine	1.66	1.29
Histidine	0.84	.....

In the glutelin containing 13.46 per cent of nitrogen, extracted

[1] Loc. cit.

[2] Ibid. 1924, **62**, 183.

[3] Z. physiol. Chem. 1922, **118**, 301.

by 0.2 per cent potassium hydroxide, after hydrolysis and separation by Fischer's ester method, Ukai and Morikawa[1] found:

	%
Glycine	0.04
Alanine	0.91
Valine	3.70
Leucine	4.42
Glutamic acid	7.89
Phenylalanine	2.51
Proline	2.38
Tryptophane	1.45
	23.30

Nitrogen Distribution.—Ukai and Morikawa also determined the nitrogen distribution with the following results: humin nitrogen 0.44, ammonia nitrogen 8.71, organic extractive nitrogen 27.76, and mono-amino nitrogen 60.48 per cent.

Fat.—The rather high percentage of fat in buckwheat middlings suggests a field for investigation. No careful study of the constituents of the fat of the polygonaceous seeds appears to have been undertaken.

Carbohydrates.—Excepting small amounts of *sugar* and *dextrin*, or allied carbohydrates, the nitrogen-free extract consists of *starch*.

Phosphorus-Organic Compounds. *Phytin.*—Averill and King[2] obtained the following amounts of phytin, calculated as $C_6H_{18}O_{24}P_6$, in buckwheat and its products: buckwheat, 2 samples, 1.25 and 2.39 per cent; hulled buckwheat 1.29 per cent; buckwheat flour 1.86 per cent; and buckwheat hulls 1.00 per cent.

Pigment of Hulls.—Fessler[3] states that the hulls contain a green pigment other than chlorophyl, which in organic solvents shows a red or brown fluorescence. The green color becomes yellow or brownish on standing. He attributes to this substance a poisonous action. Also a xanthophyl pigment, related to phytosterol, is stated to be present.

Enzymes.—An *under-maltase* with an optimum activity at 55° C. has been found by Huerre[4] in dry buckwheat. It decomposes quickly during germination.

Maltase is present in large amount, according to Wierzchowski.[5] No *peroxidase* was found by Coupin.[6]

[1] J. Pharm. Soc. Japan, 1925, **516**, 819.
[2] J. Am. Chem. Soc. 1926, **48**, 724.
[3] Z. physiol. Chem. 1913, **85**, 148.
[4] Compt. rend. 1909, **148**, 1526.
[5] Biochem. Z. 1913, **57**, 125.
[6] Compt. rend. 1925, **180**, 685.

Mineral Constituents.—Haskins, in his compilation,[1] gives the composition of the ash in parts per thousand of the grain. Calculated to the ash his results are comparable with the average of 2 early analyses by Von Bibra[2] as shown in the following table:

Composition of Buckwheat Ash

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	Cl
	%	%	%	%	%	%	%	%
Haskins.....	22.9	5.9	4.2	12.7	.....	48.3	1.7	1.7
Von Bibra.....	23.07	6.12	3.30	13.44	2.09	47.97	2.09	1.95

The average results of 2 analyses of buckwheat grits by Von Bibra[2] are: potash 25.44, soda 5.88, lime 2.30, magnesia 12.90, ferric oxide 1.80, phosphoric acid 48.11, sulphuric acid 1.68, and chlorine 1.91 per cent.

Minor Mineral Constituents. *Zinc.*—Whole seed 11.8 mg. per kilo, dry basis (Bertrand and Benzon).[3]

Iodine.—None (Winterstein).[4]

TARTARY BUCKWHEAT

Fagopyrum tartaricum Gærtn. = *F. dentatum* Mönch. = *Polygonum tartaricum* L.

Fr. Blé noir tartarique. Ger. Tartarischer Buchweizen.

This species is little grown outside of its Asiatic habitat but, is well adapted to mountainous and other regions where the season is short.

MACROSCOPIC STRUCTURE.—The *kernel* is light brown-gray, lusterless, of medium size (up to 6 mm. long), and is distorted in shape because of an irregular short tooth on one or more of the angles and irregularities of the surface. A furrow runs through the middle of each face.

[1] Massachusetts Agr. Exp. Sta., 1919, Spec. Bul.
[2] Die Getreidearten, etc. Nürnberg, 1860.
[3] Bul. soc. hyg. aliment. 1928, **16**, 457.
[4] Z. physiol. Chem. 1918, **104**, 54.

MICROSCOPIC STRUCTURE.—According to Harz,[1] the structure of *F. tartaricum* is the same in essential details as *F. rotundatum* Babingt, which he describes.

Pericarp.—In two details this differs from the pericarp of common buckwheat: (1) the *epicarp* is composed of a rather thick layer of nearly isodiametric cells with plain (not spirally thickened) walls which fit into depressions of the underlying fibers and (2) the *fibers* in the inner part of the fiber layer are longitudinally arranged and consequently cross those of the outer part at nearly right angles.

Spermoderm, Endosperm, and **Embryo** as in common buckwheat.

Chief Structural Characters.—Kernel brown-gray, furrowed, more irregular in shape than common buckwheat.

Epicarp without spiral reticulations; fibers longitudinally arranged in portions. Otherwise like common buckwheat.

BLACK BINDWEED

Polygonum Convolvulus L.

Fr. Renouée. Sp. Correguela. It. Vilucchio. Ger. Windenknöterich.

Wild buckwheat, another common name for this plant, is appropriate because of the similarity of the leaf and achene to those of true

Fig. 119.

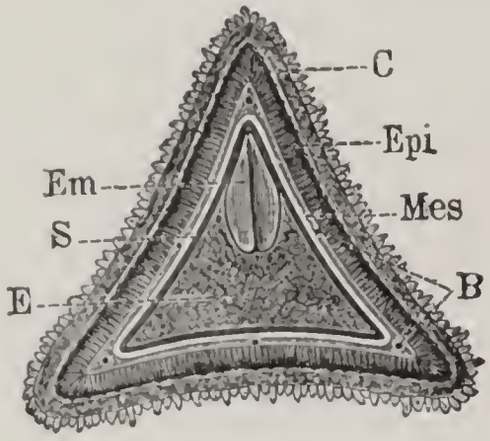


Fig. 120.

Fig. 119.—Black Bindweed. I kernel with calyx. II kernel without calyx. ×5. (A.L.W.)

Fig. 120.—Black Bindweed. Kernel in cross section. *C* calyx; *Epi* epicarp; *Mes* mesocarp; *B* fibro-vascular bundles; *S* spermoderm; *E* endosperm; *Em* embryo. ×16. (A.L.W.)

buckwheat. Its climbing habit, which enables the plant to climb on the stalk of wheat and other grains, is suggested by the name bindweed.

[1] Samenkunde. Berlin, 1885, p. 1109.

As much as 29 per cent of the fruit has been found in American screenings. (Winton.)[1] The enormous production of this weed in Minnesota, the Dakotas, and adjoining regions is further illustrated by a single shipment of a thousand tons, separated by special machinery from screenings, that came under our observation.

MACROSCOPIC STRUCTURE.—The jet black, dull, triangular *fruit* (achene) is about 3 mm. long (Fig. 119, II). The five- to six-lobed *calyx* closely invests the fruit at maturity (Fig. 119, I), the three outer lobes being keeled or winged, but as a rule is largely rubbed off in threshing, screening, and handling as is sometimes also true of the pericarp. Closely surrounding the *seed* is the light buff or colorless spermoderm. A cross section (Fig. 120) shows under the lens a *bundle* (*B*) in each angle and in the center of each face, also the *cotyledons* in one of the angles of the floury endosperm (*Em*).

MICROSCOPIC STRUCTURE.—Brief mention of certain tissues is made by Kraus.[2] Winton[3] describes in detail the tissues of the calyx, fruit, and seed.

Calyx (Figs. 120 and 121, *C*).—Three layers are present: (1) *outer epiderm* (*aep*) each cell of which is extended so as to form a blunt, conical or nipple-shaped striated papilla, (2) *mesophyl* (*m*) of chlorophyl-bearing parenchyma with intercellular spaces, and (3) *inner epiderm* (*iep*) of elongated cells more or less wavy in outline interspersed with stomata.

Pericarp (Fig. 121, *F*).—Four layers are present: (1) *epicarp* (*epi*) of radially elongated cells greatly thickened, except at the base, with deeply convoluted walls and cuticular *warts* (*w*), (2) *hypoderm* (*hy*) of somewhat elongated thin-walled cells, (3) *mesocarp* made up of parenchyma (*p*), thickest at the angles, and (4) *endocarp* (*end*), usually so compressed as to show no details of structure.

The *epicarp cells* are 100 μ high on the sides and somewhat higher at the angles. They are striking both in cross section (Fig. 121, *epi*) and in surface view (Figs. 122 and 123; Fig. 124, *epi*) because of the convolutions of the walls and the warts. A branch of the cell cavity extends into each wart.

Spermoderm (Fig. 121, *S*; Fig. 125).—Three layers are present as in buckwheat but the middle layer is different: (1) *outer epiderm* (*ae*) of wavy-walled longitudinally elongated cells, (2) detached vermiform *cross cells* (*q*) passing into isodiametric forms containing chlorophyl contents, and (3) *inner epiderm* (*ie*) of longitudinally elongated cells.

[1] Connecticut Agr. Exp. Sta. Rep. 1902, p. 341.

[2] Jahrb. wiss. Bot. (Pringsheim) 1866, **5**, 83.

[3] Z. Unters. Nahr.-Genussm. 1903, **6**, 433; Connecticut Agr. Exp. Sta. Rep. 1902, p. 346.

The *cross cells* correspond to the spongy parenchyma of buckwheat. Attention is directed to the fact that cross cells form a spermoderm tissue and not, as in the cereals, a pericarp tissue, also that in both cases detached cross cells and spongy parenchyma replace one another, being the same morphologically.

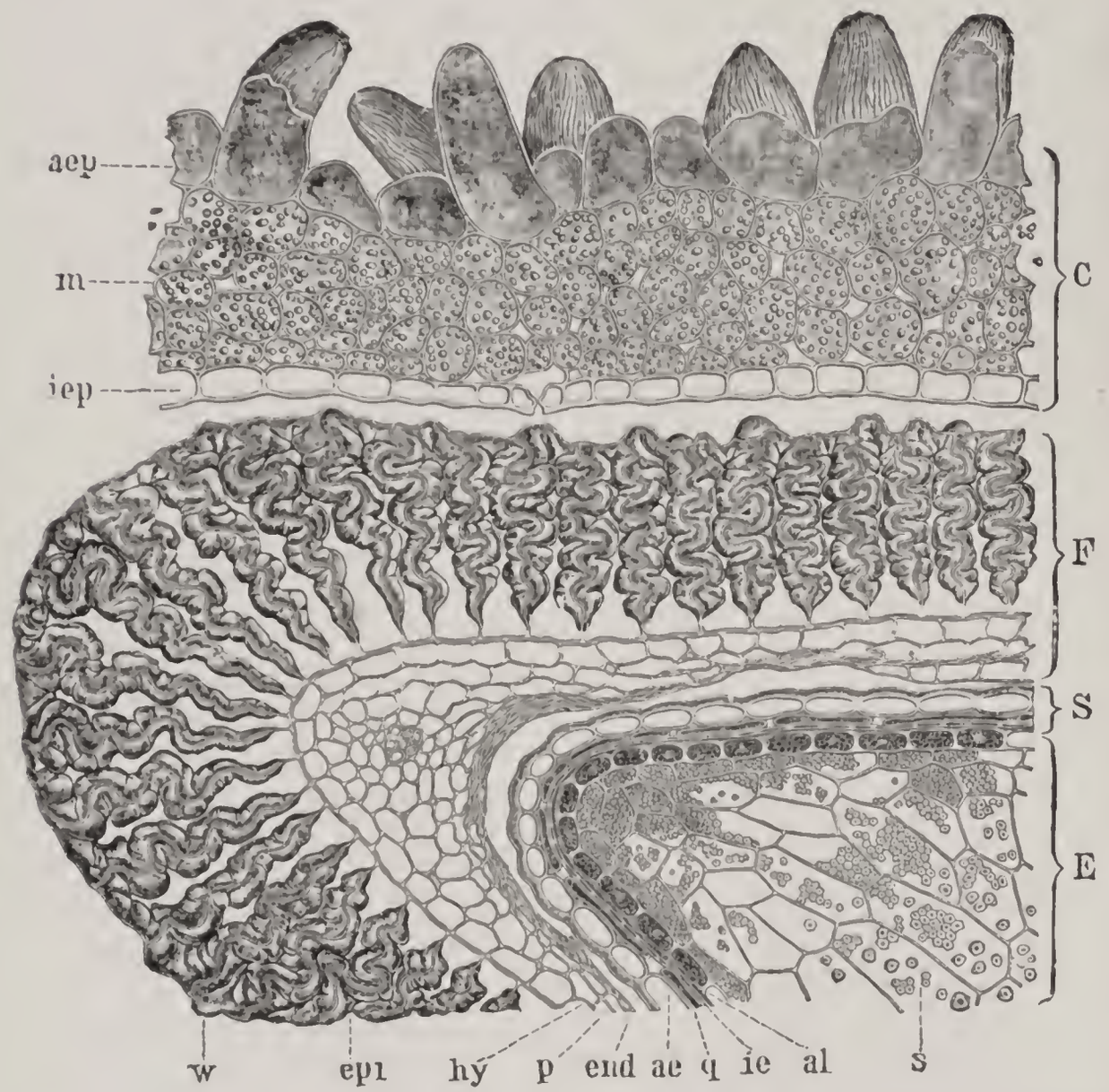


FIG. 121.—Black Bindweed. Kernel in cross section. *C* calyx: *aep* outer epiderm, *m* mesophyl, *iep* inner epiderm. *F* pericarp: *epi* epicarp with *w* warts, *hy* hypoderm, *p* mesocarp, *end* endocarp. *S* spermoderm: *ae* outer epiderm, *q* cross cells, *ie* inner epiderm. *E* endosperm: *al* aleurone cells, *s* starch cells. ×160. (A.L.W.)

Endosperm (Fig. 121, *E*; Fig. 125).—Both the *aleurone cells* (*al*) and the *starch cells* (*s*), as well as the *starch grains*, are indistinguishable from these elements in common buckwheat.

Embryo (Fig. 120, *Em*).—This may be separated by soaking the seed for some days in sodium hydroxide. The *cotyledons* are very much narrower than in buckwheat.

Chief Structural Characters.—Seed small; triangular, jet black. Embryo narrow, in angle.

Epicarp cells radially elongated, thickened, convoluted, warty.

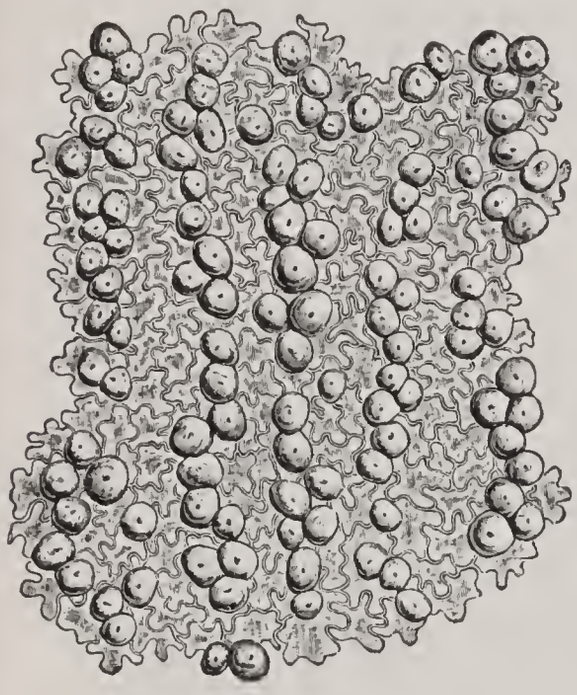


Fig. 122.

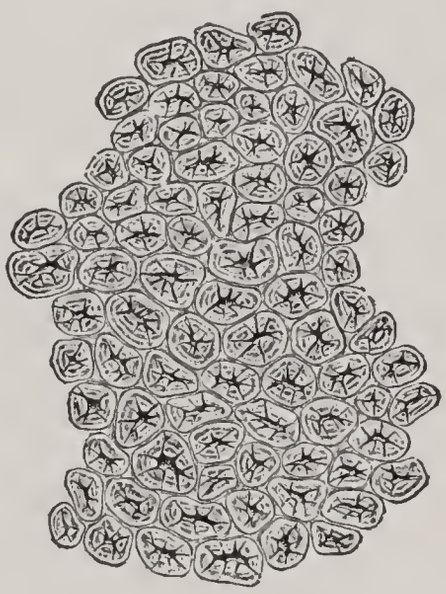


Fig. 123.

Fig. 122.—Black Bindweed. Epicarp in surface view showing cuticular warts. ×160. (A.L.W.)

Fig. 123.—Black Bindweed. Epicarp in tangential section. ×160. (A.L.W.)

Spermoderm with cross cells instead of spongy parenchyma. Otherwise similar to buckwheat.

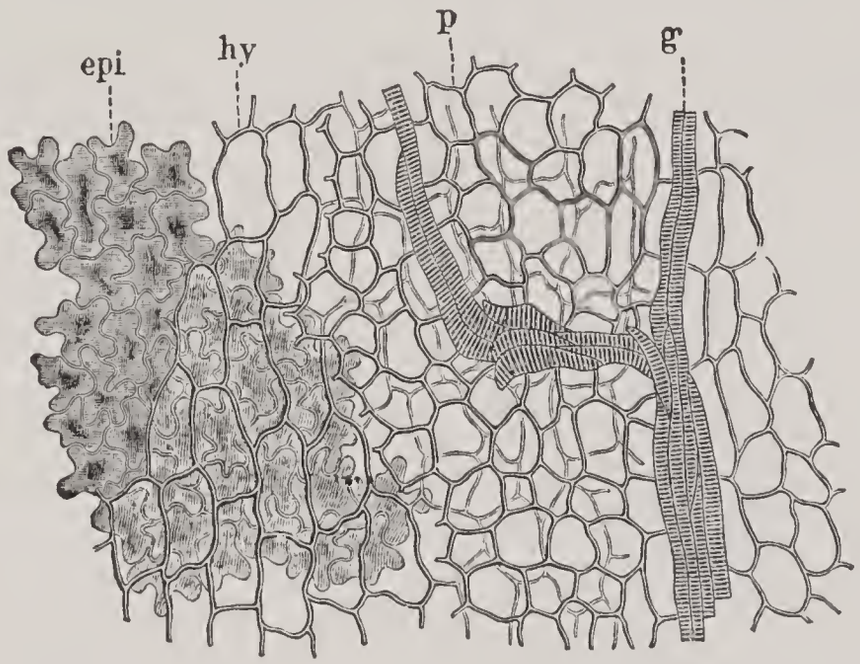


Fig. 124.—Black Bindweed. Pericarp in surface view from below: *epi* epicarp, *hy* hypoderm, *p* mesocarp, *g* fibro-vascular bundle. ×160. (A.L.W.)

MICROSCOPY OF BLACK BINDWEED PRODUCTS.—Flour which would rank with buckwheat flour in value doubtless could be

made from the seed. Identification of such flour would depend on the cross cells or possible fragments of the epicarp.

At one time, as the writers have found in the course of official inspection in Connecticut, a product made from black bindweed, containing the black hulls, as well as a portion at least of the starchy matter, was used as an adulterant of black pepper. The epicarp with its warty, wavy-walled cells is of special value in detecting such an admixture whether in a human food or a feed.

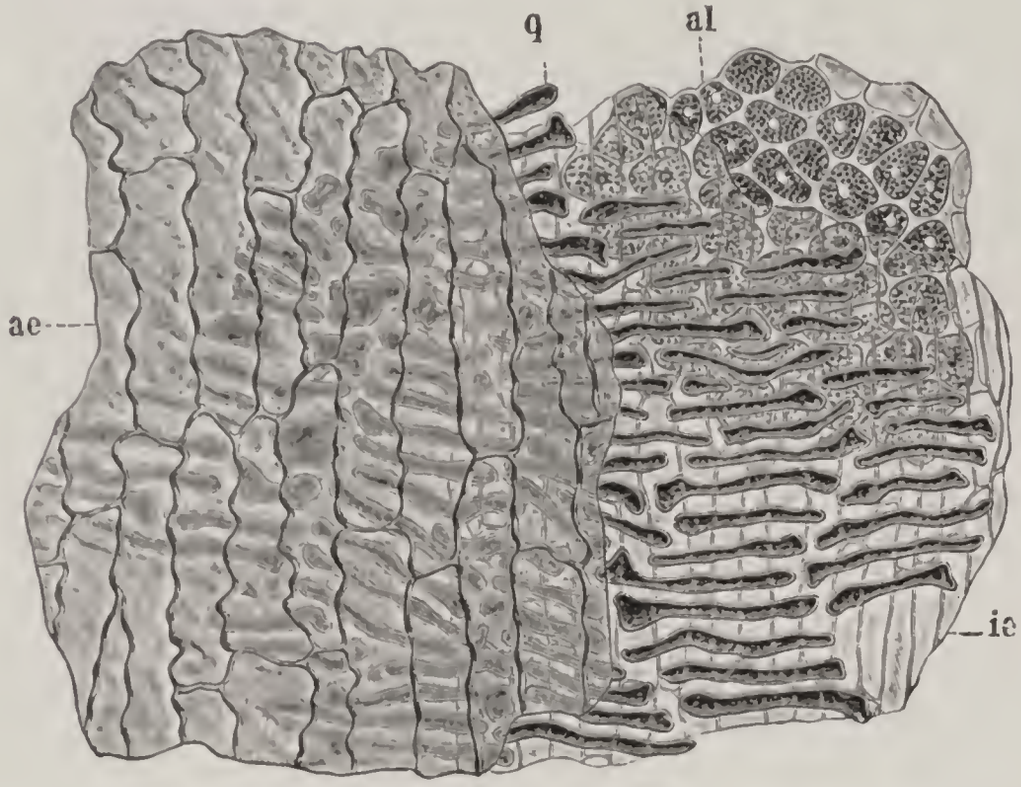


FIG. 125.—Black Bindweed. Seed in surface view. Spermoderm: *ae* outer epiderm, *q* cross cells, *ie* inner epiderm. *al* aleurone cells of endosperm. ×160. (A.L.W.)

CHEMICAL COMPOSITION.—Analyses by Winton[1] and Kling[2] follow:

COMPOSITION OF BLACK BINDWEED

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Winton	12.23	9.12	2.21	65.96	8.46	2.02
Kling	10.88	10.50	2.12	68.53	6.37	1.60

[1] Connecticut Agr. Exp. Sta. Rep. 1902, p. 344.

[2] Landw. Vers.-Stat. 1912, 78, 189.

SMARTWEED

Polygonum persicaria L. and *P. pennsylvanicum* L.

Fr. Renouée. It. Persicaria. Ger. Knöterich.

In addition to *P. Convolvulus* other species of the genus growing as weeds in grain fields yield fruits that find their way into the threshed grain and screenings. The two species named above are American examples.

MACROSCOPIC STRUCTURE.—*P. persicaria* was introduced from Europe. Usually the *fruits* are flattened, 1.5 to 2 mm. long and 1 to 1.5 mm. wide, smooth, brown or black. *P. pennsylvanicum*, a native species, has *fruits* 3 to 3.5 mm. long and 2 to 2.5 mm. wide, lustrous, brown or black. Triangular fruits also occur in both species.

MICROSCOPIC STRUCTURE.—Both species correspond closely in structure with black bindweed except that cuticular warts are absent.

CHIEF STRUCTURAL CHARACTERS.—Seed usually flattened.

Cuticular warts absent, otherwise like black bindweed.

CURLED DOCK

Rumex crispus L.

Fr. Parelle crispée. Ger. Krauser Ampfer.

This species of *Rumex* is an especially troublesome weed as it is perennial and also bears numerous seeds. Although a native of Europe it grows luxuriantly in the Western Hemisphere.

MACROSCOPIC STRUCTURE (Fig. 126).—The inflorescence is in heads (panicled racemes), often a foot or more long, made up of side branches with whorls of flowers on peduncles of different lengths. Of the six *sepals* the three inner further develop after flowering to form the "valves" enclosing the fruit; the three outer remain small and spreading. Each valve is heart-shaped, 3 to 4 mm. long, reticulated, with a tubercle ("grain") in the middle. The triangular pointed *fruit* is 2 mm. long, 1.5 mm. wide, smooth, lustrous, of a uniform medium brown color, easily separating from the valves on threshing.

A cross section shows that *bundles* occur only in the three angles, that the endosperm is floury, and that the *cotyledons* are in the middle of one of the sides with the line of separation of the two parallel with that side, not, as in black bindweed, in one of the angles.

MICROSCOPIC STRUCTURE.—Kraus[1] has studied this species.

Calyx.—The *outer epiderm* is composed of cells with deeply sinuous,

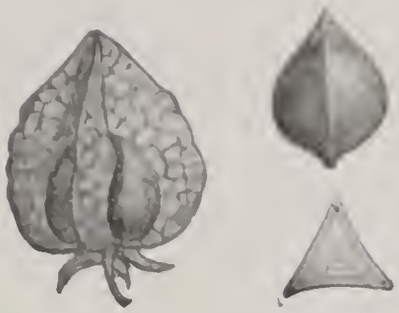


Fig. 126.

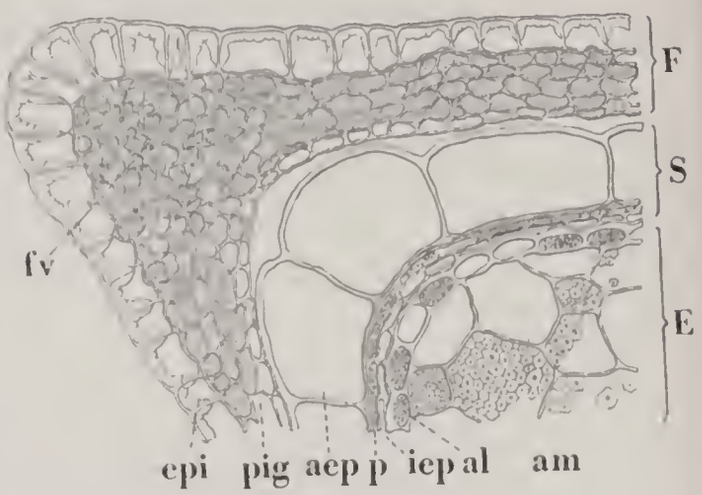


Fig. 127.

Fig. 126.—Curled Dock. Left: fruit showing valves with tubercles. Right: fruit entire and in cross section. ×5. (A.L.W.)

Fig. 127.—Curled Dock. Fruit in cross section. *F* pericarp: *epi* epicarp, *pig* brown cells with *fv* fibro-vascular bundle. *S* spermoderm: *aep* outer epiderm, *p* spongy parenchyma, *iep* inner epiderm. *E* endosperm: *al* aleurone cells, *am* starch cells. ×160. (A.L.W.)

moderately thickened walls, much like those of the pericarp but thinner-walled, and stomata. Papillæ are absent.

Pericarp (Fig. 127, *F*).—Only two layers are noticeable, the endocarp

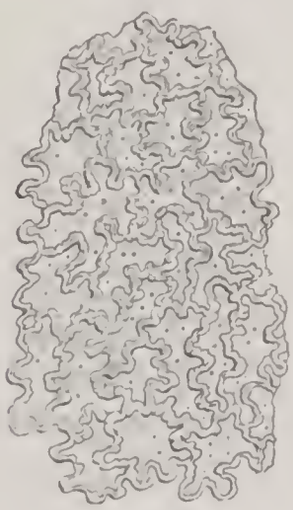


Fig. 128.

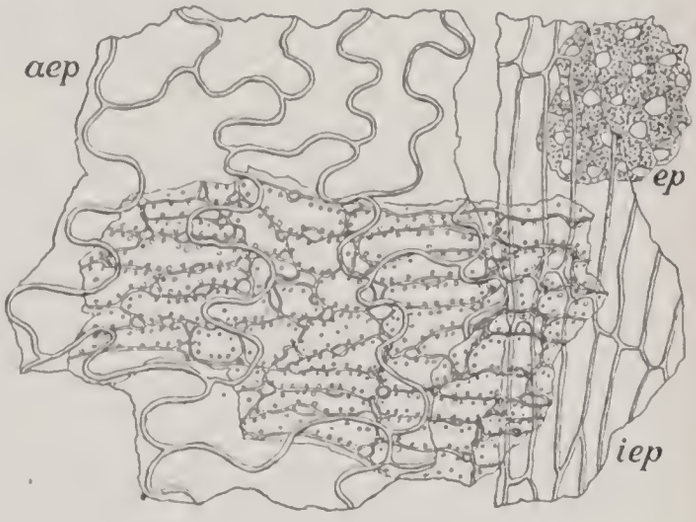


Fig. 129.

Fig. 128.—Curled Dock. Epicarp in surface view. ×160. (A.L.W.)

Fig. 129.—Curled Dock. Seed in surface view. Spermoderm: *aep* outer epiderm over spongy parenchyma with chlorophyl grains, *iep* inner epiderm. *ep* epiderm of cotyledon. ×160. (A.L.W.)

being inconspicuous or obliterated: (1) *colorless epicarp* (*epi*), similar to that of black bindweed, but without warts, and cells often tangen-

[1] Jahrb. wiss. Bot. (Pringsheim) 1866, **5**, 83.

tially elongated, the thickened sinuous walls in surface view suggesting intestines (Fig. 128), and (2) *mesocarp* (*pig*) of thin-walled more or less elongated cells with deep brown contents soluble in sodium hydroxide. The absence of sclerenchyma fibers forming a hypoderm is remarkable.

Spermoderm (Fig. 127, *S*; Fig. 129).—Three layers, analogous to those of buckwheat and black bindweed, are present: (1) *outer epiderm* of giant cells (*aep*) with deeply sinuous walls, (2) *spongy parenchyma* (*p*) consisting mostly of cross cells with small intercellular spaces, and (3) *inner epiderm* (*iep*) of longitudinally elongated cells like those of other members of the family.

The cells of the *outer epiderm* are not only much broader and longer than those of buckwheat and black bindweed but their radial diameter is much greater.

Endosperm and Embryo.—Practically the same as in buckwheat.

Chief Structural Characters.—Fruit small (2 mm.), pointed, triangular, smooth, uniform medium brown. Embryo in middle of one side.

Calyx with outer epiderm of sinuous-walled cells but no papillæ. Epicarp of sinuous-walled cells; fiber layer absent. Spermoderm with outer epiderm of large sinuous-walled cells; spongy parenchyma of transversely elongated cells. Otherwise similar to buckwheat.

WEED SEEDS OF THE GOOSEFOOT FAMILY

(*Chenopodiaceæ*)

SEVERAL species of *Chenopodium* are weeds in field and garden. Grain often contains a large amount of the seed of the species here described.

The garden vegetables, beets and spinach, belonging to this family, are treated in Volume II.

LAMB'S-QUARTERS

Chenopodium album L.

Fr. Ansérine. Sp. Quenopodio. Ger. Gänsefuss.

Both the type and the variety *viride* Moq. occur as weeds in field and garden of the Old World and (introduced) in the New World. The seed occurs with pigweed seed in grain. Because of their small size and dark color the two are hardly distinguishable to the naked eye and are collectively known as pigweed seed.

MACROSCOPIC STRUCTURE.—The plant is readily distinguished from pigweed by the dusty (not hairy) gray-green foliage and the rounded granular masses of the paniculate heads.

Unlike those of pigweed, the fruit and seed (Fig. 130) are transversely flattened, the fruit is enveloped in the five-keeled *calyx* lobes at maturity and the *pericarp* persists as a dull covering of the black seed. The *seed* itself is somewhat larger than that of pigweed, being on the average 1.5 mm. in diameter, and is not margined. As in pigweed the *embryo* forms a ring about the perisperm.

MICROSCOPIC STRUCTURE.—Literature on the microscopy of this seed is lacking although beet and spinach seeds belonging to the same family have been studied by Harz.[1] These vegetables are quite like lamb's-quarters and pigweed in the structure of the inner epiderm of the spermoderm, the perisperm, endosperm, and embryo, but the other parts, especially the outer coats of the spermoderm, are quite different.

[1] Samenkunde. Berlin, 1885, pp. 1092–1098.

Calyx (Fig. 131).—The *outer epiderm* (*aep*[1], *aep*[2]) consists of thin-walled cells with straight or gently wavy walls, stomata, and glandular *hairs*. Strikingly different are the cells of the *inner epiderm* (*iep*), which are elongated in various directions and have deeply and intricately sinuous walls.

Pericarp.—This is characterless in structure, excepting the *epicarp* (Fig. 132), which is composed of isodiametric or somewhat elongated

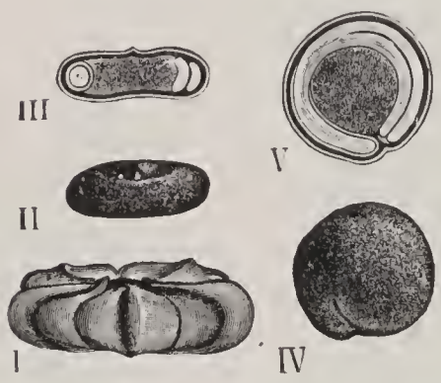


Fig. 130.

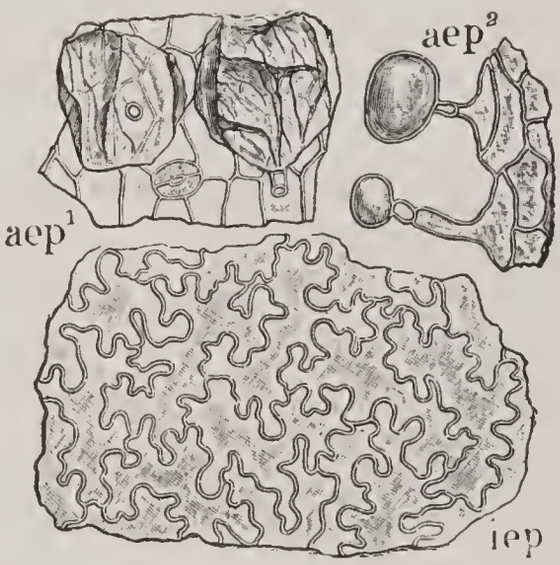


Fig. 131.

Fig. 130.—Lamb's-quarters. I fruit covered by calyx. II fruit from side. III fruit in longitudinal section showing pericarp (white), spermoderm (black), radicle sheathed in endosperm (left), perisperm (center), cotyledons (right). IV fruit from below. V fruit in cross section showing embryo coiled about perisperm. ×8. (A.L.W.)

Fig. 131.—Lamb's-quarters. Calyx in surface view. *aep*[1] outer epiderm near base with shrunken glandular hairs; *aep*[2] outer epiderm at margin with glandular hairs; *iep* inner epiderm. ×160. (A.L.W.)

cells with straight or gently wavy walls. As seen in cross section the outer wall is convex.

Spermoderm.—Although of the same general structure as in pigweed the isodiametric cells of the outer epiderm (Fig. 133) are larger, being on the average 50 μ, in tangential diameter, reaching a maximum of 110 μ, and 50 μ in radial diameter; also the stalactite-like rods are further apart. Since there is no margin there is no elongation of the cells at the edges but, as in pigweed, elongated cells occur near the hilum, over the region where the tips of radicle and cotyledons meet. Pigmentation of this layer begins earlier than in pigweed and proceeds further. When seeds reach only half their mature size they are deep black. Fully ripe seeds bleach scarcely at all when soaked in 1 : 1 Javelle water two days, whereas in pigweed they bleach overnight.

Endosperm and **Embryo** as in pigweed.

Perisperm.—The *starch grains* are minute as in pigweed but they are grouped in oval or rounded aggregates (Fig. 134).

Chief Structural Characters.—As the seeds of pigweed and lamb's-quarters occur together in grain, a comparison of the distinguishing characters is desirable.

Calyx.—*Pigweed*: narrow, spreading; *inner epiderm* with moderately wavy walls. *Lamb's-quarters*: broad, keeled lobes closing over fruit; *inner epiderm* deeply and intricately sinuous.

Pericarp.—*Pigweed*: transverse dehiscence, upper half with plumose stigmas falling away; *epicarp* cells longitudinally elongated with deeply

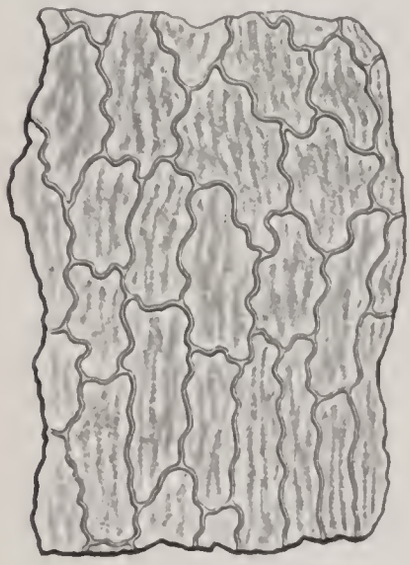


Fig. 132.

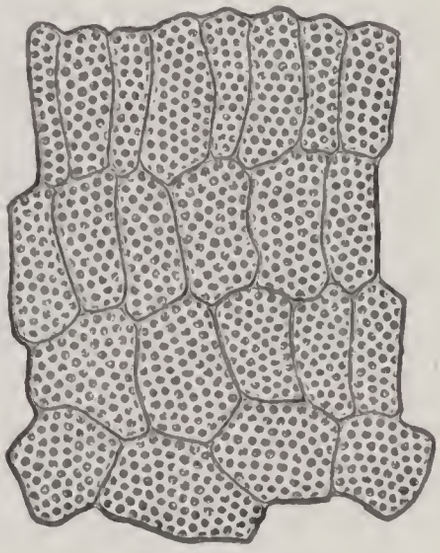


Fig. 133.

Fig. 134.

Fig. 132.—Lamb's-quarters. Epicarp in surface view. ×160. (A.L.W.)

Fig. 133.—Lamb's-quarters. Outer epiderm of spermoderm in surface view showing transition to elongated cells at the hilum. ×160. (A.L.W.)

Fig. 134.—Lamb's-quarters. Cells of perisperm showing starch grains in aggregates. ×300. (A.L.W.)

sinuous walls changing at dehiscence line to transversely elongated with straight walls. *Lamb's-quarters*: broad, keeled lobes persisting as skin on seed; *epicarp* cells longitudinally elongated or isodiametric, walls straight or slightly wavy.

Seed.—*Pigweed*: lenticular, margined, diameter 1 mm., flattened sides vertical; isodiametric *outer epiderm* cells of spermoderm average 30 μ, maximum 60 μ; starch not in aggregates. *Lamb's-quarters*: flattened, no margin, diameter 1.5 mm., flattened sides horizontal; isodiametric *outer epiderm* cells average 60 μ, maximum 110 μ, rods farther apart than in pigweed; *starch* in rounded or oval aggregates.

CHEMICAL COMPOSITION.—Maurizio,[1] in a chapter on cereal substitutes utilized for food in Russia during famines, gives a compila-

[1] Getreide, Mehl und Brot. Berlin, 1903.

tion of analyses of weed seeds, waste products, and bread made from them. Analyses by Kapoustine, Stephanowsky, Soulmeneff, and Erismann showed the following range for lamb's-quarters, calculated to the dry basis: protein 15.43 to 16.82, fat 5.82 to 8.12, nitrogen-free extract 47.72 to 49.98, fiber 18.35 to 21.45, and ash 4.77 to 6.98 per cent. The high protein and fat content and the low starch content (as shown by the nitrogen-free extract) are due to the relatively large embryo; the high fiber content is due to the relatively thick hull with perhaps adhering chaff.

The seed of *Chenopodium quinoa* L., although containing a bitter principle, is an important food in Chile and Bolivia where the plant is native. González[1] gives the composition as follows: water 12.5, protein 13.13, starch 52.82, cellulose 12.2, and ash 5.44 per cent. The ash contained: potash 38.86, lime 3.01, magnesia 11.53, ferric oxide 1.87, phosphoric acid 41.05, and silica 1.48 per cent. He states that the bitter principle is *saponin*. According to Lubsen,[2] the plant was cultivated in Germany during the World War. The bitter taste may be removed by boiling water. An analysis of the seed gave: water 15.5, protein 17.2, fat 4.9, starch 48.7, cellulose 1.8, and ash 5.5 per cent. Saponin was found to be present, but whether this was the bitter principle was not determined.

[1] Investigación del Chenopodium quinoa. La Paz, Bolivia, 2 ed., 1917.
[2] Pharm. Weekbl. 1918, **55**, 887.

WEED SEEDS OF THE AMARANTH FAMILY

(*Amarantaceæ*)

This small family, closely related to the goosefoot family, is of interest chiefly because of a number of weeds belonging to the genus *Amarantus* of which one is here described. At least one species is used as greens in the Orient.

PIGWEED

Amarantus retroflexus L.

Fr. Amarante. Ger. Fuchsschwanz.

Pigweed, also known as red-root, and lamb's-quarters, plants of two closely related genera, natives of the Old World, now infest grain fields and gardens the world over. Both have seeds so small as to permit their removal from grain by sieves with meshes too fine to allow the grain to pass. Cargoes and carloads, consisting chiefly of these fine seeds, are handled in the grain centers of the United States and Canada for use in cattle foods. By grinding them to a fine powder danger of disseminating a noxious weed seed is obviated.

In China the young plant of pigweed or a closely allied species is valued as a vegetable. It is also grown for this purpose in the United States by gardeners supplying the Chinese colonies.

MACROSCOPIC STRUCTURE (Fig. 135).—The *plant* is more or less hairy; the green or reddish dense branched spikes are crowded together in close panicles. The five narrow *sepals* persist at maturity at the base of the one-seeded fruit. As a result of splitting through a transverse line of dehiscence, the upper part of the dry *pericarp* separates as a crown-like cap with three spreading plumose *stigmas*.

The campylotropous *seed*, thus liberated, is lenticular, 1 mm. in diameter, margined, smooth, black, and lustrous. It stands on edge in the pericarp. Sections cut through the margin show under a lens the *embryo*, the *radicle* of which is encased in a thin sheath of endosperm, curved so as to form a ring about the starchy perisperm. The narrow *cotyledons* are about the same length as the radicle.

MICROSCOPIC STRUCTURE.—Since at harvest time some of the seeds are not mature and are still encased in the calyx and pericarp, the structure of these parts, as well as the seed, should be understood.

Calyx (Fig. 136).—The *outer epiderm* (*aep*) consists of longitudinally elongated cells which, except at the base, parts of the edge, and the very tip, have wavy walls. Near the base at the edges occur one- to several-celled *hairs* (*t*). The *inner epiderm* is much like the outer epiderm except that the walls are not wavy.

Pericarp (Fig. 137).—Both *epicarp* (*aep*) and *endocarp* consist of more or less longitudinally elongated cells with strongly sinuous walls,

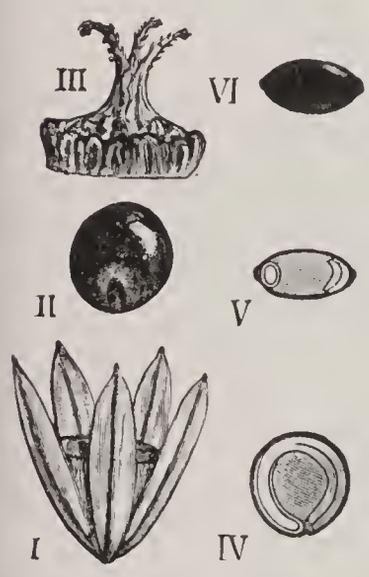


Fig. 135.

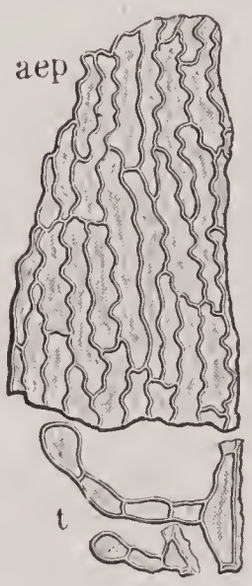


Fig. 136.

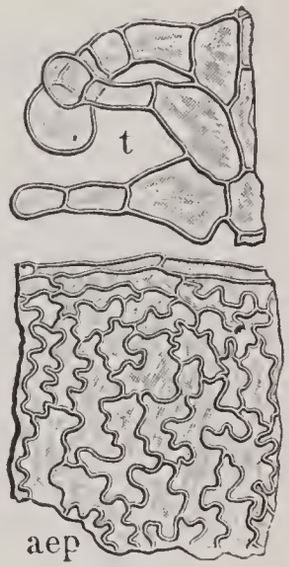


Fig. 137.

Fig. 135.—Pigweed. I calyx and bottom of pericarp. II whole seed. III top of pericarp with stigmas. IV seed in longitudinal section showing embryo, with radicle sheathed by endosperm, curved about perisperm. V seed in cross section. VI whole seed from below. ×8. (A.L.W.)

Fig. 136.—Pigweed. Calyx in surface view. *aep* outer epiderm at margin near tip; *t* hairs from margin near base. ×160. (A.L.W.)

Fig. 137.—Pigweed. Pericarp in surface view. *aep* epicarp showing transitions at line of dehiscence from wavy-walled to narrow straight-walled cells; *t* hairs from stigma. ×160. (A.L.W.)

passing, at the dehiscence line in both base and cap, into transversely elongated cells with straight walls. Jointed *hairs* (*t*), often with glandular tips, occur on the stigmas.

Spermoderm (Fig. 138, *S*; Fig. 139).—Cross sections of the seed, held in cork, may be cut with a Gillette blade. Soaking whole seeds for a day or two in 1 : 1 Javelle water bleaches the outer epiderm and permits the removal entire of the embryo and endosperm. Staining with chlorzinc iodine or safranin differentiates the tissues.

Three layers are present, the first and third being characteristic: (1) *outer epiderm* (*aep*), composed of isodiametric cells except at the

margins and near the hilum where they are elongated, with stalactite-like rods in the greatly thickened outer tangential walls, (2) *middle layer* (*p*) of parenchyma, compressed in the dry seed, and (3) *inner epiderm* (*iep*) of netted cells with spiral or spiral-reticulated thickenings.

The *outer epiderm* is studied with difficulty in cross sections of the mature seed owing to the black pigment and collapsed inner and side walls. Treatment of carefully prepared sections with Javelle water to bleach and expand the tissues and chlorzinc iodine to stain them brings out the structure, the rods staining dark blue and the meshes about them light blue. At the margin the elongation of the cells follows along the curve of the circumference; at the hilum it extends from the center

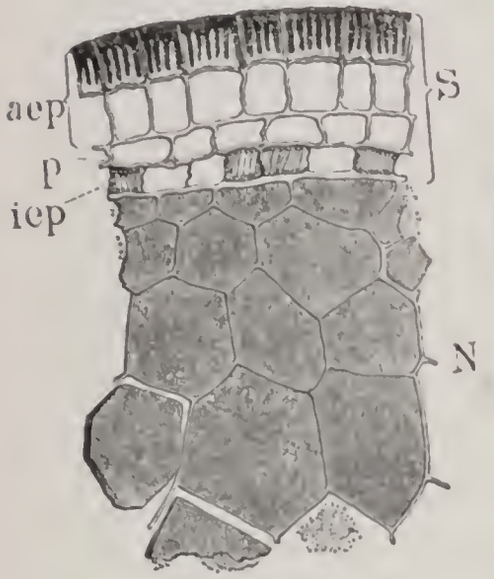


Fig. 138.

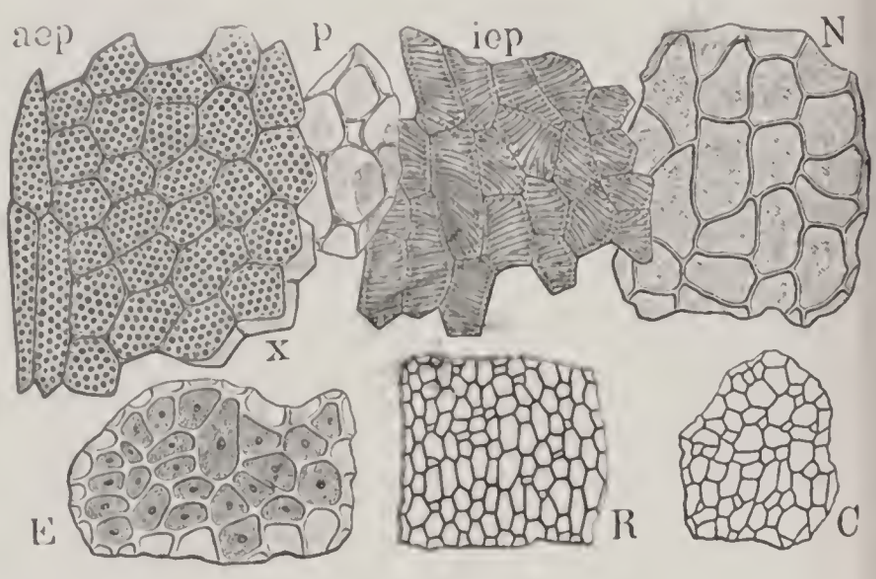


Fig. 139.

Fig. 138.—Pigweed. Seed in cross section. *S* spermoderm: *aep* outer epiderm with thickened outer walls, *p* parenchyma, *iep* inner epiderm with spiral-reticulated thickenings. *N* perisperm with masses of minute starch grains. ×160. (A.L.W.)

Fig. 139.—Pigweed. Elements of seed in surface view. *N* outer layer of perisperm; *E* endosperm; *R* epiderm of radicle; *C* epiderm of cotyledon. Other reference letters as in Fig. 138. ×160. (A.L.W.)

toward the margin over the surface depression. The average height of the layer is about 60 μ, the average diameter of the isodiametric cells as seen in surface view is about 30 μ, and the maximum diameter 60 μ.

The *inner epiderm* resembles that of the strawberry spermoderm. At the edges of the seed the spiral thickenings are most distinct. Chlorzinc iodine treatment brings out an inner cuticle often having radial walls of the outer layer of the perisperm attached to its surface.

Perisperm (Figs. 138 and 139, *N*).—This *starchy tissue* is like that in the perisperm of lamb's-quarters, cockle, and other caryophyllaceous seeds except that the grains do not appear to be in aggregates but in masses filling the cells. Similar, but somewhat larger, starch grains

occur in the perisperm of pepper. Measured in the masses their maximum size is 2 μ; their average size, 1 μ or less. When isolated the Brownian movement prevents accurate measurement.

Endosperm (Fig. 139, *E*).—Starch-free *aleurone cells* constitute the thin endosperm which caps the radicle.

Embryo.—The *outer epiderms* of radicle (Fig. 139, *R*) and cotyledons (*C*) consist of larger and smaller cells, some of the latter developing later into stomata. Cross sections of the radicle show an outer zone of *periblem* and an inner *plerome cylinder* of smaller cells. Delicate *procambiun bundles* pass through the cotyledons.

Chief Structural Characters.—See Lamb's-quarters.

CHEMICAL COMPOSITION.—A study of the composition of pigweed seed has been carried out by Harding and Egge.[1] Seeds were stripped from plants growing in southern Minnesota and cleaned free of chaff and other foreign matter. About 75 per cent of the seeds were black and fully mature; the remainder were red and more or less immature. Analysis yielded the following results: water 8.60, protein 19.13, fat 7.24, reducing sugar trace, sugar after inversion calculated as sucrose 2.15, hemicellulose (" starch " by acid conversion minus starch by diastase) 7.59, starch by diastase 33.39, fiber 10.92, ash 4.46, and tannin and other undetermined constituents by difference 6.52 per cent.

[1] J. Ind. Eng. Chem. 1918, **10**, 529.

WEED SEEDS OF THE PINK FAMILY

(*Caryophyllaceæ*)

NUMEROUS species belonging to this family are garden flowers and some are troublesome weeds, the seeds of which occur in grain. The seeds are rich in starch but are regarded as injurious even to animals because of the presence of saponins although more evidence on this point is desirable.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *sepals* and *petals* (if present) each number four or five, the sepals often being grown together at the base. Usually the *pod* is one-celled and many-seeded, campylotropous seeds being borne on a central placenta. In most of the species the *embryo* and its sheath of *endosperm* are curved about the bulky *perisperm*, making the seed kidney- or snail-shaped. The color, size, and shape of the seeds, characters of importance in diagnosis, are as follows: *Lychnis Githago* (corn cockle) dark brown, 3 to 4 mm., kidney-shaped, very rough; *L. alba* (white cockle) light blue-gray, 1 mm., kidney-shaped, rough; *Saponaria Vaccaria* (cow cockle) black, 2 to 3 mm., round, smooth; *S. officinalis* (soapwort) black, 1.8 to 2.2 mm., kidney-shaped, rough; *Silene noctiflora* (night-flowering catchfly) gray-brown, 1 to 1.5 mm., kidney-shaped, rough; *S. Cucubalus* (bladder campion) gray-brown, 1 to 1.5 mm., kidney-shaped, rough; *Spergula arvensis* L. (common spurrey) dark brown, 1 to 1.5 mm., flattened-globular with light-colored narrow margin.

COMPARATIVE MICROSCOPIC STRUCTURE.—The seeds of the various genera are more or less similar.

Spermoderm.—Only the *outer epiderm* is conspicuous. The cells are commonly brown or black, thick-walled, and extended outward to form slight dome-like elevations (cow cockle, soapwort) or papillæ which may be long, conical or club-shaped (corn cockle, bladder campion), or short (white cockle, night-flowering catchfly). In surface view the cells are jagged in outline. Minute warts cover the surface of all the seeds here described except cow cockle and soapwort. The *inner epiderm* of cow cockle has distinct spiral-reticulations which are absent or indistinct in the other species.

Perisperm.—The perisperm is packed with minute *starch grains* united into oval or elongated aggregates. In white cockle and bladder

campion the starch grains reach 4 μ, in night-flowering catchfly 3 μ, and in soapwort, cow cockle and common spurrey 2 μ, whereas in corn cockle they seldom exceed 1 μ. Distinct spiral-reticulations are evident on the cells of the *outer perisperm* of corn cockle and cow cockle on removal of the starch by sodium hydroxide or heating with chloral hydrate.

Endosperm and Embryo.—Both are starch-free.

COMPARATIVE CHEMICAL COMPOSITION.—Analyses of corn cockle show somewhat more protein, fat, fiber, and ash and less nitrogen-free extract than wheat of average composition. No proximate analyses of other members of the group and no ash analyses of any seeds of the family are available.

Githagin, a supposedly toxic substance, occurs in cockle, and this or a related saponin may be present in other members of the group.

CORN COCKLE

Agrostemma Githago L. = *Lychnis Githago* Lam.

Fr. Nielle des blés. It. Gettaione. Ger. Kornrade.

Hanausek, Moeller, Schimper, and other European authors name corn cockle as the most common weed seed in grain. Among American authors, Oswald [1] states that it is the most common weed seed in wheat owing to the difficulty of separation. It was present in 43 per cent of the samples of seed wheat examined by him in 1910 and 1911, this percentage being greater than that for any other weed seed. Wilson [2] and Selby [3] refer to its frequent occurrence and the difficulty of removal from grain.

Figures are not available as to the actual percentages of cockle in unpurified threshed grain, but the fact that cockle is a minor though frequent constituent of screenings would of itself indicate that other weed seeds are produced in greater amount, the stress laid on cockle being because of the difficulty of its removal and the belief that because of the presence of githagin (sapotoxin, agrostemin), a glucoside of the saponin group, it is injurious to health.

Among weeds in general, corn cockle is by no means the most troublesome. Beal [4] states: "In no sense a weed except in wheat," and Cox [5] does not list it among the fifty worst weeds in the United States.

[1] Minnesota Agr. Exp. Sta. 1912, Bul. **127**, 147.
[2] Ibid. 1906, Bul. **95**, 214.
[3] Ohio Agr. Exp. Sta. 1906, Bul. **175**, 323.
[4] Michigan Agr. Exp. Sta. 1910, Bul. **260**, 128.
[5] U. S. Dept. Agr. 1922, Farm. Bul. **660** rev. 29.

The plant is a native of Europe and was introduced into the United States in seed grain.

MACROSCOPIC STRUCTURE.—The *calyx*, below, consists of a ten-ribbed tube, 2 to 2.5 cm. long, and above, of five narrow, pointed leaf-like lobes about equaling the tube, each lobe with a central rib and two marginal ribs resulting from the splitting of the tube ribs, the whole persisting after the five somewhat shorter rose-red petals fall. The *ovary* ripens into a capsule, somewhat longer than the calyx tube, with a short central placenta on which are borne the numerous seeds at the ends of thread-like funiculi of different lengths.

Characteristic of the campylotropous *seed* (Fig. 140) are its size (3 to 4 mm.), its irregular kidney shape, its dark brown color and the rows of coarse tooth-like papillæ which roughen the surface. A longitudinal section cut through the center of the *embryo* shows that the latter is coiled about the central perisperm, the hilum being where radicle and cotyledons nearly meet. On soaking a seed for some days in sodium hydroxide the brown spermoderm and the embryo, with the thin *endosperm* forming a cap on the radicle, may be separated.

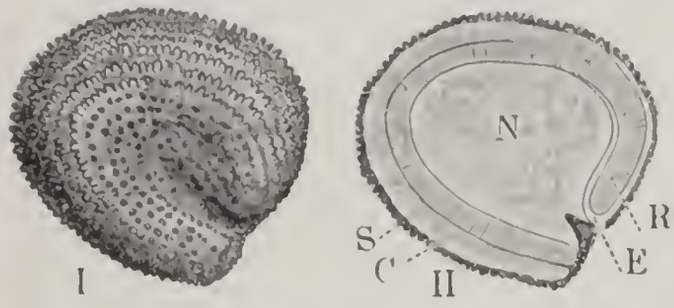


Fig. 140.—Corn Cockle. I whole seed. II seed in longitudinal section: *S* spermoderm; *E* endosperm; *R* radicle; *C* cotyledons; *N* perisperm. ×8. (A.L.W.)

MICROSCOPIC STRUCTURE.—Harz in "Landwirthschaftliche Samenkunde," published in 1885, describes in detail the morphology and histology of corn cockle as seen in cross section. Although in this seed, as in others throughout his book, the appearance in surface view is not noted, he brings out the following fundamental points quite overlooked by later authors so far as we have observed: (1) that the starchy tissue of this as well as all other caryophyllaceous seeds studied by him is perisperm and not endosperm as commonly stated, (2) that the outer layers of this perisperm have spirally reticulated walls, and (3) that the endosperm is represented by a sheath, at most a few cells thick, over the end of the radicle. Moeller [1] evidently saw the spiral reticulations but inferred that they belonged to the inner epiderm of the spermoderm, and Vogl [2] considered them as belonging to a single layer of perisperm, the remainder having disappeared. Both authors and others who have accepted their conclusions have regarded the true per-

[1] Mikroskopie Nahr.-Genussm. 1 Aufl. 1886, p. 162; 2 Aufl. 1905, p. 247.

[2] Wicht. Nahr.-Genussm. Berlin, 1899, p. 39.

isperm of Harz as endosperm and make no mention of the true endosperm over the radicle.

Harz found that the general structure not only of all the caryophyllaceous seeds studied by him but also of the seeds of *Phytolacca* (*Phytolaccaceæ*), as well as of beet and spinach (*Chenopodiaceæ*), is the same to the extent that the starchy portion is perisperm and the non-starchy radicle sheath of the curved embryo is endosperm. All this appears to be logical and consistent, but his assumption that the aleurone layer and starchy parenchyma of buckwheat and other polygonaceous seeds is perisperm is unwarranted since in these we find no corresponding radicle sheath that could be classed as endosperm, while the aleurone layer and the starchy parenchyma with grains of considerable size have all the characters of endosperm.

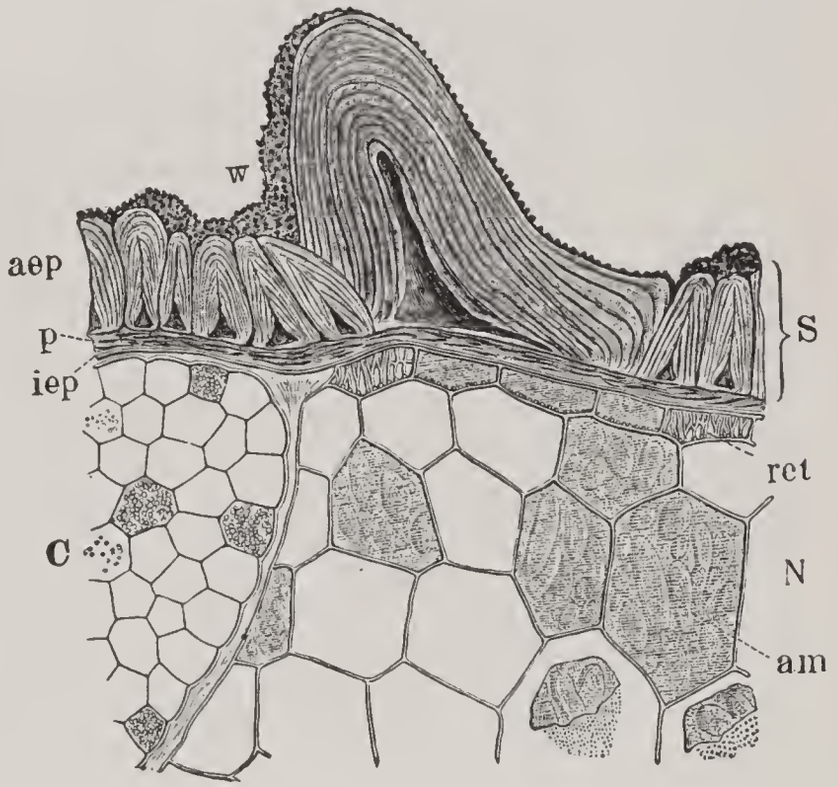


Fig. 141.—Corn Cockle. Seed in cross section. *S* spermoderm: *aep* outer epiderm with *w* cuticular wart, *p* compressed parenchyma, and *iep* inner epiderm with cuticle. *C* cotyledon. *N* perisperm with reticulated cells in outer layer and *am* masses of starch grains. ×160. (A.L.W.)

If the structure of the seed be regarded as fundamental in classification, the polypetalous *Caryophyllaceæ* are closely related to the apetalous *Chenopodiaceæ* and *Amarantaceæ*, thus warranting their inclusion in the group *Curvembryæ* Schnitzl, although our usual classification separates them widely; on the other hand the *Polygonaceæ* seems far removed from the *Chenopodiaceæ* and the *Amarantaceæ*, although commonly regarded as closely allied.

Spermoderm (Fig. 141, *S*; Fig. 142).—For study in surface view, the coloring matter should be removed by heating with sodium hydroxide or bleaching with Javelle water. Three layers are present: (1) *outer epiderm* (*aep*) of huge brown cells, wavy in contour with enormously thickened walls extended beyond the surface as warty, blunt conical or club-shaped papillæ, (2) brown *parenchyma* (*p*), more or less spongy or irregular forming a collapsed tissue, and (3) *inner epiderm* (*iep*), also collapsed, of thin, straight-walled, often elongated but not reticulated cells.

Of these only the *outer epiderm* is conspicuous, the warty papillæ being more pronounced than in the other common members of the group. The middle layers of parenchyma are somewhat confused and not easily distinguished from the inner epiderm. Spiral-reticulated markings of the *inner epiderm* are not evident, furnishing a distinction from cow cockle.

Perisperm (Figs. 141 and 143, *N*).—On treatment with sodium hydroxide or chloral hydrate, spiral-reticulated markings of the outer cells are evident both in surface view and cross sections. The largest of the minute *starch grains* measures scarcely over 1 μ, their accurate

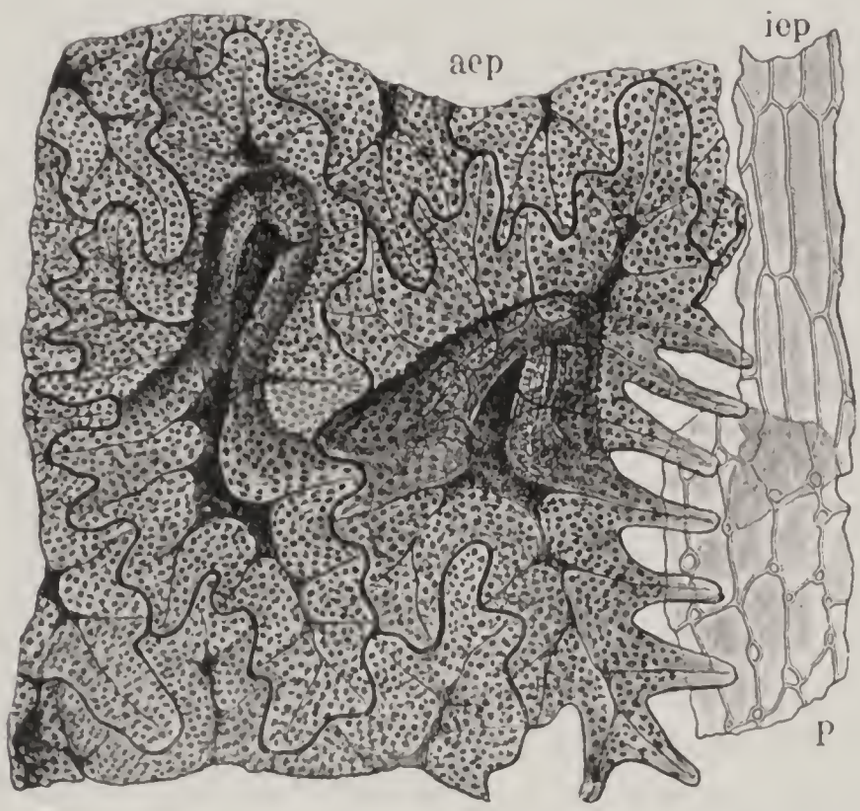


FIG. 142.—Corn Cockle. Spermoderm in surface view. *aep* outer epiderm; *p* spongy parenchyma of subepidermal layers; *iep* inner epiderm. ×160. (A.L.W.)

measurement when free being difficult owing to the lively Brownian movement. Many of them are consolidated in much elongated oval or club-shaped aggregates.

Endosperm (Fig. 143, *E*).—At the thickest part the tissue is only a few cells thick. The cells resemble the aleurone cells of the cereals, having rather thick walls and finely granular contents free from starch.

Embryo (Figs. 141 and 143).—Throughout, the cells are thin-walled and the contents are non-starchy. The *epiderm* (dermatogen) of the radicle (*R*) is made up of cells of uniform size, those of the cotyledon (*C*) of large and small cells, the latter later developing into stomata. The *periblem* of the radicle is of collenchyma surrounding the small-celled *plerome* cylinder. In the cotyledons *procambium bundles* are recognized in cross section by their small size.

Chief Structural Characters.—Seed very rough, dark brown, irregularly kidney-shaped, 3 to 4 mm., larger than other common seeds of the family. Embryo, with radicle sheathed by endosperm, coiled about perisperm.

Outer epiderm of spermoderm warty with dark brown, much thickened, wavy walls and club-shaped or blunt conical papillæ. Perisperm with spirally reticulated outer cells and minute (1 μ) starch grains in elongated aggregates.

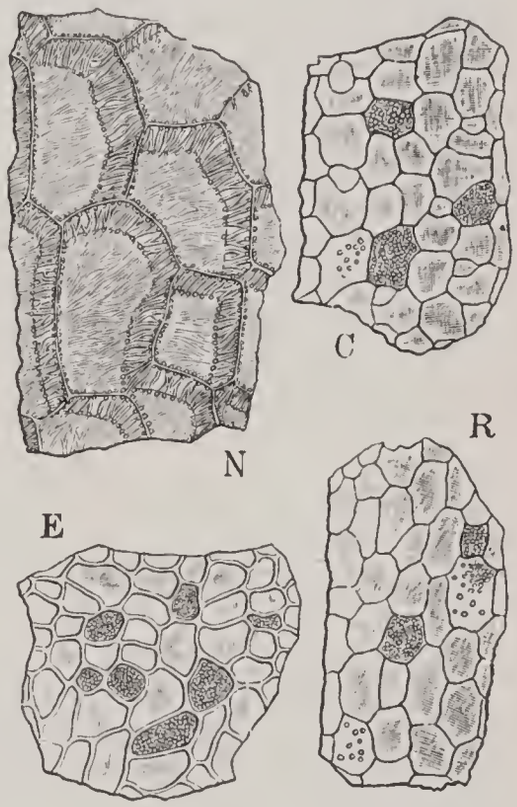


Fig. 143.—Corn Cockle. Elements of inner portion of seed in surface view. *N* outer layer of perisperm; *E* endosperm; *C* outer epiderm of cotyledon; *R* epiderm of radicle. ×160. (A.L.W.)

CHEMICAL COMPOSITION.—Of a number of analyses of corn cockle those published by Klein (Harz),[1] Lehmann and Mori,[2] and Kling[3] suffice to show its composition. See table on following page.

Notwithstanding the hull, which contributes a high fiber content, the relatively large starch-free embryo is reflected in moderately high percentages of protein and fat.

Saponin.—*Agrostemma-sapotoxin*, also known as *agrostemmin* and *githagin*, was found by Christophsohn[4] in corn cockle to the extent of 6.51 per cent. Kruskal[5] decided that its formula is $C_{17}H_{26}O_{10} + H_2O$ or $C_{17}H_{28}O_{11}$. Saenger[6] carried out further studies. Brandl,[7] in purifying the saponin, obtained agrostemmic acid which made up 6 to 7 per cent of the crude substance. This acid on hydrolysis yields *sapogenin*, $C_{35}H_{54}O_{10}$.

Opinions differ as to the toxicity of this saponin. Pusch considers cockle under some conditions injurious, but animals soon become accustomed to it. Young animals are more susceptible than old. Grown cattle, sheep, and rodents are little affected; calves, swine, and horses are more or less susceptible. Whether fowls are affected seems doubtful.

[1] Landw. Samenkunde. Berlin, 1885, p. 1078.
[2] Arch. Hyg. 1889, **9**, 257.
[3] Landw. Vers.-Stat. 1912, **78**, 189.
[4] Dis. Dorpat, 1874.
[5] Arb. Dorpat Pharm. Inst. 1891, **6**, 105.
[6] Dis. München, 1904.
[7] Landw. Vers.-Stat. 1910, **72**, 326; Arch. Exp. Path. Pharm. 1908, **59**, 224.

Composition of Corn Cockle

	Water	Protein	Fat	Saponin	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Klein	10.9	15.6	6.7	.....	63.1		3.7
Lehmann and Mori:							
As produced	11.5	14.5	7.1	6.5	47.9	8.2	4.0
Saponin-free	11.5	15.3	6.8	.....	51.2	8.6	4.3
Kling	11.2	16.1	5.9	.....	57.0	6.3	3.3

Extensive feeding experiments by Kornauth and Arche[1] indicated that the toxic action of corn cockle has been exaggerated. They regard it a valuable and harmless food for growing pigs.

BLADDER CAMPION

Silene Cucubalus Wibel = *S. latifolia* Brit. et Rendle = *S. inflata* Smith

Fr. Silénée gonflée. Ger. Taubenkropf-Nelke.

Once an ornamental, this plant, a native of Europe, is now a cosmopolitan weed. It is a perennial and the young shoots are said to be eaten like asparagus in England (Bailey). Harz[2] describes the fruit and seed and states that the plant is grown for fodder. In the United States the seed does not now appear to occur in grain, although its abundance in the writers' section forbodes trouble in the future.

MACROSCOPIC STRUCTURE.—Characteristic is the inflated *calyx* with tube 1.5 cm. long, ending in five teeth, 1 cm. long. Five main calyx ribs extend into the teeth with three smaller ones on each face making a total of twenty. Their green color on the white background is striking. The five white or pink *petals* are two cleft. Numerous gray-brown, rough seeds, 1 to 1.2 mm., are borne on the central placenta.

MICROSCOPIC STRUCTURE.—The *outer epidermal cells* of the spermoderm are not so deeply pigmented as are those of corn cockle nor do papillæ reach such length but otherwise are similar. The starch grains reach 4 μ.

Chief Structural Characters.—Seed gray-brown, rough, kidney-shaped, 1 to 1.2 mm.

Spermoderm similar to that of corn cockle. Starch grains up to 4 μ.

[1] Landw. Vers.-Stat. 1892, **40**, 177.

[2] Samenkunde. Berlin, 1885, p. 1079.

COW COCKLE

Saponaria Vaccaria L. = *Vaccaria vulgaris* Host. = *V. parviflora* Mönch. = *V. pyramidata* Wett. = *Lychnis Vaccaria* Scop.

Ger. Kuhkraut.

In Europe, its native habitat, cow cockle, or cow herb, ranks among the most troublesome weeds in grain fields. Beal [1] states that it is a very troublesome annual in Spring wheat of Michigan, but most of the weed bulletins of the American Experiment Stations ignore it; it is, however, included in the second series (each series of twenty-four seeds) of weed seeds distributed by the Minnesota Station.

MACROSCOPIC STRUCTURE.—The *seed* is quite evenly rounded, 2 to 3 mm. in diameter, black, smooth but dull to the naked eye, and faintly roughened under a lens. The arrangement of endosperm, embryo, and perisperm is as in corn cockle.

MICROSCOPIC STRUCTURE.—Most of the authors have confined their attention to the outer epiderm; Vogl,[2] however, describes other tissues and devotes an entire page to illustrations. As in the case of corn cockle, he considers the starchy tissue to be endosperm and overlooks the true endosperm covering the tip of the radicle. He pictures spiral cells and describes them as remnants of the perisperm.

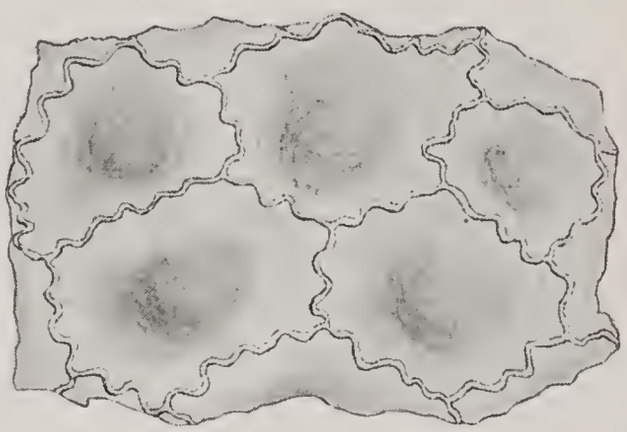


Fig. 144.—Cow Cockle. Outer epiderm of seed in surface view. ×160. (A.L.W.)

Spermoderm.—Owing to the black color little detail is evident in surface view even after treatment with sodium hydroxide. On bleaching with Javelle water for a short time the structure of the *outer epiderm* (Fig. 144) is clearly evident. This has deeply sinuous walls, much as in corn cockle, but the walls are only moderately thickened and the outer wall is merely convex without being extended into papillæ; furthermore, warts are absent.

The *inner epiderm* is a yellow tissue with polygonal, isodiametric or somewhat elongated cells remarkable for the spiral-reticulated thickening of the walls, a peculiarity which if present in any other seeds of the group here described is not conspicuous. In this detail cow cockle agrees with the seeds of pigweed and lamb's-quarters.

[1] Michigan Agr. Exp. Sta. 1910, Bul. **260**, 128.

[2] Wicht. Nahr.-Genussm. Berlin, 1899, p. 43.

Perisperm.—The outer cells have spiral-reticulated thickenings, but present a different appearance from those of the inner epiderm of the spermoderm because of the larger size of the cells and the absence of color.

The *starch grains* are 2 μ or less in diameter and occur in rounded or oval aggregates.

Endosperm and **Embryo** much as in corn cockle.

Chief Structural Characters.—Seed black, smooth, round, 2 to 3 mm.

Outer epidermal cells of spermoderm deeply sinuous in outline, convex but without elongated papillæ, non-warty. Starch grains up to 2 μ.

SOAPWORT

Saponaria officinalis L. = *Bootia vulgaris* Neck.

Fr. Saponaire. Sp. Saponaria. It. Saponaria. Ger. Seifenkraut.

Bouncing-bet, or soapwort, ordinarily has light pink single or double flowers but there are varieties with flowers of various shades of red. It is a perennial escaped from cultivation and has attracted the attention of weed experts in both Europe and the United States.

MACROSCOPIC STRUCTURE.—The narrow, tubular *calyx* (becoming broader on ripening) is obscurely five-nerved, two-lobed, and five-toothed. The five to six *petals* have spreading or reflexed blades and a forked appendage at the top of the narrow claw. The *fruit* is four-ribbed and opens by four valves at the apex. Numerous flattened, kidney-shaped, distinctly roughened *seeds* are borne on a central placenta. The seeds are black and 1.8 to 2.2 mm. in their longest diameter.

MICROSCOPIC STRUCTURE.—Although the *epidermal cells* are much more convex than those of cow cockle, they are not extended to form marked papillæ and are not warty. The starch grains seldom exceed 2 μ.

Chief Structural Characters.—Seed kidney-shaped, rough, black, up to 2.2 mm.

Spermoderm with non-warty convex epidermal cells. Starch grains up to 2 μ.

WHITE COCKLE

Lychnis alba Mill. = *L. vespertina* Sibth. = *Melandryum album* Garcke.

Evening campion, or white cockle, is a night-flowering ornamental biennial escaped from gardens. It is included in the first series

(twenty-four) of weed seeds distributed by the Minnesota Agricultural Experiment Station.

MACROSCOPIC STRUCTURE.—The plant is viscid and hairy; the *calyx* tube is 2.0 to 2.5 cm. long with narrow teeth; the flowers are white. The *seeds* are irregular kidney-shaped but differ strikingly from corn cockle in being only about 1 mm. in diameter and of a light blue-gray color due to a bloom which disappears in water, leaving the seed of a medium brown color.

MICROSCOPIC STRUCTURE. Spermoderm.—The *outer epidermal cells* are somewhat smaller (75 to 150 μ in diameter) and the papillæ are much shorter than in corn cockle. Warts are present. Reticulations are absent in the *inner epiderm.*

Perisperm.—Reticulations are absent or not evident. The *starch grains* are noticeably larger than in corn and cow cockle, pigweed, and lamb's-quarters, reaching 4 μ in diameter. They occur in rounded or oval aggregates.

Endosperm and Embryo.—As in corn cockle.

CHIEF STRUCTURAL CHARACTERS.—Seed light blue-gray, rough, kidney-shaped, 1 mm.

Spermoderm with short papillæ and numerous warts. Starch grains up to 4 μ.

NIGHT-FLOWERING CATCHFLY

Silene noctiflora L.

Fr. Silénée. Ger. Nachtleimkraut.

Like several other weeds of the group this plant is an ornamental from Europe escaped from cultivation in various parts of the United States.

MACROSCOPIC STRUCTURE.—The plant is viscid and hairy, the *calyx tube* longer (2.5 to 3.5 cm.) and the *seed*, which is gray-brown, larger (1 to 1.5 mm.) than that of white cockle which it otherwise resembles.

MICROSCOPIC STRUCTURE.—No distinct difference in structure from that of white cockle has been noted. Cells of the *outer epiderm* (up to 175 μ) have short warty papillæ; the *inner epiderm* and *outer perisperm* do not show reticulations; and the *starch grains* (up to 3 μ) occur in aggregates.

CHIEF STRUCTURAL CHARACTERS.—Seed resembles white cockle but larger (1 to 1.5) and gray-brown.

Starch grains up to 3 μ.

COMMON SPURREY

Spergula arvensis L.

Fr. Spergule. Sp. Esparcilla. It. Asteroide. Ger. Ackerspergel.

Common or corn spurrey is a European weed occurring also in American grain fields.

MACROSCOPIC CHARACTERS.—Characteristic of the rough, black, flattened-globular seed is the thin light colored, halo-like margin which encircles it almost completely.

MICROSCOPIC STRUCTURE. Spermoderm.—The *outer epiderm* is characterized by the thick wavy outline, seen in surface mounts, the striking club-shaped outgrowths of the cells, and the conspicuous warts.

Perisperm.—The starch grains vary up to 2 μ.

CHIEF STRUCTURAL CHARACTERS.—Seed black, rough, flattened-globular, margined. Spermoderm with warty club-shaped outgrowths; starch up to 2 μ.

SEEDS OF THE WATER-LILY FAMILY

(*Nymphæaceæ*)

The oriental lotus which yields edible rhizomes also produces farinaceous seeds similar to the cereals in food value.

LOTUS SEED

Nelumbo nucifera Gærtn. = *Nelumbium speciosum* Willd.

Fr. Lotus sacré. It. Loto. Ger. Lotos.

Blasdale [1] notes the occurrence in Chinese markets of San Francisco of the shelled seed, a larger form being known as "seung lin" and a smaller and more common form as "pak lin." He states that the seeds are eaten by the Chinese either raw, boiled, or roasted and are also used in soup and for the preparation of starch (which see).

Seeds of the smaller form were found by the writers on sale in New York Chinatown.

MACROSCOPIC STRUCTURE.—The *fruit* is a black nut with a bluish bloom, reaching 2 cm. in length and 1 cm. in breadth, abruptly narrowing at the tip to a short point and at the base ending in a slight depression. Pericarp and spermoderm are grown together, separation of the hard shell (nearly 1 mm. thick) from the thin skin adherent to the cotyledons being through a zone with numerous longitudinal bundles. A cavity is present between the hard white cotyledons which make up the bulk of the seed. The short radicle and the plumule with its sheath are at the apex of the seed. Being bitter the plumule is removed before cooking.

MICROSCOPIC STRUCTURE.—The shell, consisting of the consolidated **Pericarp** and **Spermoderm,** has four coats: (1) *epicarp* of narrow, radially elongated cells interspersed with somewhat larger crystal cells and sunken water stomata, (2) *palisade layer* of colorless cells up to 160 μ high, with a light line in the outer portion, (3) *sclerenchmya layer,* often over 500 μ thick, of cells with thick beaded walls, and (4) *spongy parenchyma* with here and there sclerenchyma cells containing a dark substance.

Cotyledons.—Characteristic of the cell walls are the pores forming beads. The *starch grains* (Plate III, Fig. 31) are mostly oval, pear-

[1] U. S. Dept. Agr. Off. Exp. Sta. 1899, Bul. 68, 39.

shaped, or kidney-shaped, up to 35 μ long with a central hilum and often a cleft through the longer diameter suggesting that in the starch of leguminous seeds. See section on Commercial Starches.

Chief Structural Characters.—Nut elongated, short pointed, with black shell and thin skin adherent to the bulky cotyledons.

Epicarp with crystal cells and sunken water stomata; hypoderm of palisade cells (160 μ); mesocarp and spermoderm of spongy parenchyma. Cotyledons containing elongated starch grains (35 μ) with central hilum and often rifts.

CHEMICAL COMPOSITION.—In the table below appear analyses by Blasdale [1] of the kernels of a large and a small seeded form of lotus ("*Nelumbium speciosum*") and an analysis by Langley [2] of the kernels of Chinese lotus which, although designated "*Nymphæa tetragona*," were probably from the same species as Blasdale's samples. The true Egyptian lotus is a *Nymphæa*, but the plant commonly known under that name is the oriental species of *Nelumbium*.

Composition of Lotus Seed

	Water	Protein (N×6.25)	Amides	Fat	Starch	Sucrose	Reducing sugars	Other carbohydrates	Fiber	Ash
Blasdale:	%	%	%	%	%	%	%	%	%	%
Large seeds	8.72	16.64	1.17	2.44	51.64	4.09	2.41	7.88	3.15	3.03
Small seeds	9.40	17.73	0.09	2.96	40.63	9.55	....	12.63	2.95	4.15
Langley.....	12.2	18.7	.....	2.3	41.2	....	....	19.1*	2.5	4.0

* Pentosans 3.2.

Carbohydrates.—Hemmi [3] found in the cotyledons of lotus seed (shelled seed) nearly 6 per cent of non-reducing sugars consisting largely of raffinose with a small amount of sucrose.

Mineral Constituents.—Langley [2] gives the following analysis of the ash of the kernel:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	Other constituents
%	%	%	%	%	%	%	%
36.90	0.01	6.25	9.23	0.08	trace	37.00	10.53

[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**, 41.

[2] J. Am. Chem. Soc. 1907, **29**, 1513.

[3] J. Col. Agr. Hokkaido Imp. Univ. 1921, **9**, 249.

SEEDS OF THE PEA FAMILY

(*Leguminosæ*)

NUMEROUS starchy and non-starchy seeds of legumes are described under Vegetables, Volume II. The starchy seed of the bean tree, like the chestnut, resembles the cereals in composition and accordingly is included in this volume.

BEAN TREE SEED

Castanospermum australe Cunn.

Like so many Australian and Polynesian plants, the bean tree or Moreton Bay chestnut and the only other species of the genus have certain characters not found in legumes indigenous to the other continents. The seed is eaten roasted in Australia and from it is prepared a commercial starch.[1]

The tree has been introduced into California and Florida.

MACROSCOPIC STRUCTURE.—The papilionaceous yellow flowers are in racemes. The stipitate ovary later becomes a *pod* reaching 20 cm. or more in length with several seeds remarkable among legumes for their size, which is greater than that of a horse chestnut. They resemble the latter in color and form.

The *seed* is flattened on the hilum side at right angles to the inner surfaces of the cotyledons, reaching a length and breadth of 5 cm. and a thickness of somewhat less. Particularly striking is the hilum, which is often over 4 cm. in length and about 5 mm. wide. The greater part of its breadth is taken up by several light-colored bundles running through the entire length of the broad hilum slit, the continuation of which constitutes the raphe. A strophiole is not evident, but the raphe and chalaza are pronounced. In the dried seed the spermoderm is about the thickness of writing paper and readily cracks away from the loose embryo. The cotyledons are fleshy; the radicle short and straight.

[1] Authentic seeds and starch were generously furnished by the late J. H. Maiden, F.L.S., Director of the Botanic Gardens, Sydney, New South Wales.

MICROSCOPIC STRUCTURE.—Except for Wiesner's description [1] of bean tree starch, literature is lacking.

The **Spermoderm** tissues are analogous to those of other leguminous seeds, consisting of (1) *palisade cells* up to over 110 μ high and 25 μ broad, with flat outer end, a cuticle 6 μ thick and walls of uniform medium thickness, (2) *subepiderm* of spool-shaped cells up to 40 μ high and over 100 μ broad, and (3) *parenchyma.*

All the cell walls, except those of the inner parenchyma which is much compressed and colorless, are of a yellow-brown color.

The structure about the hilum is remarkable in that the palisade cells do not double and the broad hilum slit is filled with strongly developed bundles containing numerous vessels as well as elongated reticulated and porous sclerenchyma elements, flanked on either side up to the inner compressed parenchyma by a broadened mass of yellow-brown parenchyma tissue. These bundles extend the whole length of the hilum and pass into the tissues of the raphe, apparently replacing the groups of porous sclerenchyma cells such as occur beneath the hilum slit in common garden legumes.

Endosperm.—Not evident.

Embryo.—The *cotyledons* are made up throughout of isodiametric cells with thickened, somewhat porous walls and bundle elements. The *starch grains* (Plate II, Fig. 21), similar to those of tapioca but somewhat smaller, occurring singly or more commonly in aggregates of two or more individuals, are described in the section on Commercial Starches. They are of particular interest because of the obvious compound nature of the aggregates since the compound or half compound grains of most common legumes have been hitherto mistaken for individuals.

Of interest also are the procambium bundles, which have well-developed spiral or spiral-reticulated vessels.

Chief Structural Characters.—Seed large (5 cm.), plano-convex, brown, with long hilum (4 cm.), thin spermoderm, fleshy cotyledons, and straight radicle.

Palisade cells up to over 110 μ high and 25 μ broad with medium thick walls and thick cuticle; subepiderm of spool-shaped cells up to 40 μ high and 100 μ broad; sclerenchyma group of hilum slit replaced by bundles with vascular elements; starch in aggregates of the tapioca type but component grains smaller.

[1] Die Rohstoffe des Pflanzenreiches.

NUTS OF THE HORSE-CHESTNUT FAMILY

(*Hippocastanaceæ*)

THE horse-chestnut, formerly classed under *Sapindaceæ* and its subfamily *Sapindeæ*, is the only species here considered.

HORSE-CHESTNUT

Æsculus Hippocastanum L.

Fr. Marron d'Inde. Sp. Castaño de Indias. It. Ippocastano. Ger. Rosskastanie.

As the French and Spanish names indicate, the horse-chestnut tree is a native of Asia. It was early introduced as an ornamental first into Europe and later into America.

MACROSCOPIC STRUCTURE.—The *flowers* with tubular calyx and four to five irregular petals in a dense head are much more conspicuous than those of its relatives, the maples. Although the *ovary* has three cells, each with two ovules, usually only one in each cell or one or two in the whole fruit reach maturity. The prickly *fruit* splits into three valves liberating the campylotropous, irregularly rounded *seeds* which are 2.5 to 4 cm. in diameter. Excepting the scar, which is dull gray, about 2 cm. in diameter, the seed is deep brown and lustrous. A section cut so as to pass longitudinally through the radicle shows that the spermoderm, which in most parts is less than 1 mm. thick, becomes somewhat thicker at the micropyle and is extended as a partition nearly 1 cm. long between the radicle and the cotyledons. The greater part of the seed consists of the bulky cotyledons.

MICROSCOPIC STRUCTURE.—Harz [1] describes and figures the structure in cross section.

Spermoderm.—The tissues are: (1) *outer epiderm* of radially elongated cells, (2) *outer brown coat* of many layers of isodiametric cells with thick brown walls, (3) *inner brown coat* similar to the last but the cells are tangentially elongated, and (4) *colorless cells* with thin walls.

Perisperm and Endosperm.—Only traces.

[1] Samenkunde. Berlin, 1885, p. 947.

Embryo.—The thin-walled parenchyma contains *starch grains* described under Commercial Starches and shown in Plate I, Fig. 11.

CHEMICAL COMPOSITION.—Repeated effort has been made, particularly during the World War, to make the rich store of nutrients in the kernel of the horse-chestnut available for animals and even human beings. The tree is exceedingly productive and the large size of the nuts facilitates harvesting and shelling, but the bitter taste is forbidding.

Serger [1] states that the bitter principle may be removed sufficiently for animals by boiling the coarsely ground nut with several portions of water. If in addition the material is treated with 1 per cent potassium (or sodium) carbonate solution, to remove the last traces of the bitter principle, and then with 50 per cent alcohol to extract a disagreeable sweet-tasting substance, a fairly palatable product is obtained acceptable even to humans. Serger in experiments with animals showed that the untreated nut is less obnoxious to calves than to hogs and sheep.

Kling [2] believes that the nut in moderate amount is suitable for animal feeding. He found a higher protein and fat content in nuts from trees growing on soils deficient in calcium than on soils with a generous supply of this element.

Auld [3] states that the nuts are not poisonous to animals fed in such quantities as they will eat. He gives the following analyses by Fischer of the kernel (83 per cent), the shell (17 per cent), and the whole nut:

Composition of Horse-chestnuts

	Water	Protein	True protein	Fat	N-f.ext.	Sugar	Fiber	Ash
	%	%	%	%	%	%	%	%
Kernel	2.22	12.08	8.77	6.26	74.45	2.51	2.13	2.86*
Shell	7.06	5.66	4.37	0.89	71.58	.....	13.15	1.66†
Whole nut	3.04	10.99	.....	5.34	73.97	.....	4.00	2.66

* P_2O_5 in ash 29.11 per cent. † P_2O_5 in ash 12.19 per cent.

No injurious substance was found in the nut by Chaplet.[4] He recommends boiling to remove the bitter taste or mixing with molasses.

Baker and Hulton [5] have analyzed 4 samples of horse-chestnuts after

[1] Chem. Z. 1916, **40**, 221.
[2] Landw. Vers.-Stat. 1910, **73**, 397.
[3] J. Soc. Chem. Ind. 1913, **32**, 173.
[4] Rev. chim. ind. 1913, **24**, 215.
[5] Analyst 1917, **42**, 351.

shelling, grating, drying at 55° C. and grinding. The utilization of the nuts for alcohol production was considered as they contain much starch and have marked diastatic properties.

Composition of Horse-chestnut Kernel (Baker and Hulton)

	Water	Protein (N×6.25)	Fat	Starch (Lintner)	Starch (taka-diastase)	Reducing sugars as dextrose	Sucrose	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Min...	1.8	7.2	5.0	21.9	15.2	1.6	7.3	4.7*	2.0*	2.4
Max...	3.5	10.8	7.2	47.8	39.0	9.1	17.5	5.4*	2.6*	2.9
Aver...	**2.6**	**8.9**	**6.3**	**38.7**	**32.7**	**4.4**	**11.0**	**5.09***	**2.3***	**2.7**

* Two samples.

Fat.—*Physical and Chemical Values* have been determined by Chaplet,[1] who notes the similarity to almond and mustard oil, and by Heiduschka and Zeileis.[2] The latter worked on the ether extract of the nut which had been previously extracted with hot alcohol to remove part of the saponins.

Values of Horse-chestnut Oil

	Sp. gr. 15° C.	Refrac. index	Saponification No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Hehner No.	Acetyl No.	Acid No.	Unsaponifiable matter
										%
Chaplet..	0.926	1.4747	194.5	95.4	1.54	.....	92.5	13.5	.....	
H. and Z..	.....	1.4710	175.5	99.0	1.01	0.42	92.79	....	11.67	2.50

Tannin is abundant in the bark and occurs also in the shell. Rochleder considered its formula to be $C_{13}H_{12}O_6$.

Saponins.—*Esculin* or *Esculinic Acid* ($C_6H_{10}O_5 \cdot C_9H_6O_4 + 1\frac{1}{2}H_2O$) is a glucoside occurring in all parts of the plant, particularly in the bark and shell. It splits up into *esculetin* ($C_9H_6O_4 + H_2O$) and *d*-glucose, due according to Sigmund[3] to the action of an enzyme, *esculase*.

Masson[4] found *esculinic* and *esculic acids* in the cotyledons and classed them as "saponoides."

[1] Loc. cit.

[2] Z. Unters. Nahr.-Genussm. 1917, **33**, 446.

[3] Monatsh. Chem. 1910, **31**, 657.

[4] Bul. sci. pharmacol. 1918, **25**, II, 65.

De Vevey[1] describes *argyrin* (argyrenetin) formed together with glucose on splitting up Frémy's argyrescin by acid. Whether argyrin is identical with esculetin and argyrescin with esculin does not appear.

Other substances were described by Rochleder but the work needs confirmation.

Which of the saponins is most responsible for the bitter taste of the endosperm seems uncertain.

Mineral Constituents.—According to Chaplet,[2] 12 to 30 per cent of phosphoric acid is present in the ash.

Minor Mineral Constituents. *Iodine.*—None (Winterstein).[3]

[1] Ibid. 1908, **15**, 696.
[2] Loc. cit.
[3] Z. physiol. Chem. 1918, **104**, 54.

NUTS OF THE WATER CHESTNUT FAMILY

(*Hydrocaryaceæ*)

Species of the aquatic genus *Trapa* have starchy nuts eaten as such or made into bread. Nuts of *T. natans* L., the common European species, have four horns; those of *T. bicornis* L., a Chinese species, two horns. *T. bispinosa* Roxbg. is an Indian species; this name is also applied to the Chinese plant whether or not it is the same species. All three are known as horn chestnut or water chestnut, the former name being here used to avoid confusion with the so-called water chestnut, which is a corm.

HORN CHESTNUT

Trapa bicornis L.

Chin. Ling-kok. Jap. Hishi-mo-mi.

Jesuits' nut is another name for this aquatic species said to be one of the five principal food grains of China. It is sold by Chinese merchants in the United States both to their countrymen for food and to sight-seers as curios. Starch is made from the seed in China and has been found by the writers on sale in the United States.

MACROSCOPIC STRUCTURE.—As suggested by the Latin and English names, the *nut* is two-horned, resembling a cow's head (Fig. 145). The *shell* is thin, dull black on the surface, tough but light in weight by reason of spongy tissues. When fresh, the *seed* is closely united to the pericarp, but on drying, separation takes place, leaving most of the spermoderm attached to the single hard white cotyledon.

Fig. 145.—Horn Chestnut. Fruit. ×½. (A.L.W.)

MICROSCOPIC STRUCTURE.—The **Pericarp** consists of (1) *epicarp* with black contents, (2) *hypoderm* of small cells, with thick porous walls, passing into (3) *mesocarp* of large cells, some variously elongated, and (4) *endocarp* of narrow, transversely elongated cells.

Characteristic of the **Spermoderm** are the large elongated *crossing cells* with delicate spiral markings.

Cotyledons.—*Starch* (Plate III, Fig. 26) is the only visible constituent. The grains, reaching 40 μ in length, are elliptical, kidney-shaped, rounded triangular, or quadrilateral, often with one or two swellings. They have either a central or somewhat eccentric hilum. Rings are distinct and bright crosses appear with polarized light. Aggregates of two or three small grains are present. Delicate spiral vessels occur in the procambium bundles.

Chief Structural Characters.—Nut black, two-horned. Pericarp breaks away from thin spermoderm and single cotyledon.

Epicarp with black contents; mesocarp cells large, some variously elongated; endocarp cells narrow, transversely elongated. Spermoderm cells with spiral markings. Starch grains up to 40 μ long, of rounded forms, often with swellings.

CHEMICAL COMPOSITION.—An analysis of the dried nut, grown in China but sold in San Francisco, was made by Blasdale,[1] who states that the kernel resembles the chestnut in consistency and taste. A sample of the green nut, grown in India, was analyzed by Brahmachari and Chatterjee.[2] They state that the flour is used in making sweetmeats and a condensed milk product known as *khir*. A third analysis was made by Chung and Ripperton,[3] who give two Latin names, *T. bicornis* and *T. natans*, and two English names, Jesuits' nut and " water caltrops."

Composition of Shelled Horn Chestnut

	Water	Protein	Pure protein	Fat	N-f.ext.	Red. sugar	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Blasdale	10.59	10.88	10.42	0.65	73.90	3.95	60.39	1.41	2.57
B. and C.	84.58	2.37	.....	0.18	11.39	2.25*	9.14	0.56	0.92
C. and R.	80.00	3.49	.....	0.02	15.33	.....	.....	0.36	0.80

* Soluble carbohydrates.

Mineral Constituents.—The following analysis of the ash is by Brahmachari and Chatterjee.[2]

The high percentage of soda may be due to growth in brackish water.

[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] Indian Med. Gaz. 1927, 62, 365.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. 60.

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	$CaCl_2$
%	%	%	%	%	%	%	%	%	%
9.7	19.9	2.5	1.7	0.9	0.5	25.1	13.1	0.8	3.6

The low percentages of potash and magnesia and the footing, which lacks over 20 per cent of 100, need explanation. Whether the percentage of calcium chloride includes calcium not included in the percentage of oxide is uncertain.

Chung and Ripperton[1] found in the shelled nut: calcium 0.016, phosphorus 0.128, and iron 0.0020 per cent.

[1] Loc. cit.

PART II

OIL SEEDS

PART II

OIL SEEDS[1]

In this part are described not only oil seeds, including oil nuts and weed seeds free from starch, but a few (such as the cashew nut and peanut) in which starch is present although not in sufficient amount to warrant classification with starchy seeds.

The term "seed" is used in the popular sense to include not only true seeds but also dry fruits, such as the achenes of the sunflower and other composite species, from which the worthless pericarp does not separate easily from the seed proper. Only in the case of the olive, Chinese olive, ginkgo, and avocado (the last two described in Volume II under the head of Fruit) is the succulent fruit flesh the seat of a rich store of oil.

Relation of Family to Oil Content.—A study of the composition of the seed in connection with the order of arrangement of the families from the lowest to the highest, according to Engler and Prantl, shows that as a rule an oily seed is a characteristic of the higher families, although there are marked exceptions. Thus seeds of the two families of food plants lowest in the scale, namely the ginkgo and pine families, though containing starch, also have a rich store of oil, and even the cereals that follow in the list have an oily embryo although on the whole the seed is preeminently starchy. Again the beechnut is oily whereas the acorn and the chestnut, although belonging to the same family, are starchy.

Still more important exceptions occur among the legumes, some of which have oily, others starchy seeds.

Generalizations from food seeds alone are likely to lead to unscientific conclusions; furthermore, the arrangement of families is more or less tentative and open to revision. Until we have more complete knowledge of fundamental laws and chemical reactions concerned in the formation of carbohydrates and glycerides of the fatty acids, speculations on the reasons for the deposition of one of these great classes of food substances at the expense of the other seems futile.

Location of Oil.—In the majority of the families the oil is deposited largely in the embryo of the seed with only a small amount in the endosperm. Such is the case in the following families: walnut, birch (e.g.

[1] Includes oil nuts.

filbert), beech (e.g. beechnut), mulberry (e.g. hemp), mustard, rose (e.g. almond), bursera (e.g. pili nut), cashew (e.g. pistachio); mallow (e.g. cotton), bombax (e.g. kapok), lecythia (e.g. Brazil nut), and composite. In the Brazil and paradise nuts the oil is in the enlarged radicle, but in the other families the bulk is in the cotyledons.

Families in which the oil is largely in the endosperm, only a trace or small part being in the embryo, are as follows: palm (cocoanut, palm nut), olive, pine, and parsley (e.g. wild carrot).

In the following families the oil is divided between the embryo and the endosperm: flax (e.g. linseed) and pedalium (e.g. sesame).

While in the lowest families, namely ginkgo, pine, and palm, the oil is largely or in considerable part in the endosperm, and in the highest family, composite, it is largely in the embryo, the intermediate families conform to no general rule.

Nature of Oil (Ether Extract).—In the case of oil seeds the ether extract consists largely of true fatty oil and does not contain any appreciable amount of chlorophyl such as is present in many green vegetables. Volatile ether extract, that is essential oil, which is the characteristic constituent of different parts of the umbelliferous plants and various spices, is also absent except in wild carrot.

Proteins.—High oil content of seeds is usually associated with high protein content and consequently low carbohydrate content. The proportion of protein is further increased by pressing out part of the oil in the manufacture of commercial oils, oil cakes being as a consequence "concentrated" feeds.

Microscopic examination alone usually suffices to show the high protein content as aleurone grains occur in great numbers with the fat in the cells.

Carbohydrates.—In the majority of cases the nitrogen-free extract consists entirely of carbohydrates other than starch such as gums, pentosans, and sugars (raffinose in cottonseed, etc.). A moderate amount of starch is present in some seeds such as the peanut, cashew nut, ginkgo seed, and pine nut. These statements concern only seeds with thin-walled cells; those with reserve material in large amount in the thick walls, such as vegetable ivory, are classed with oil seeds because they are non-starchy.

Enzymes.—Fernández and Pizarroso,[1] operating with 9 representative oil seeds—almond, hazelnut, walnut, maize, peanut, pine kernels, castor bean, poppy, and hemp—have carried out comprehensive studies of enzymes including proteases, lipases, urease, glycerophosphatase, and oxidases.

[1] An. soc. españ. fis. quim. 1917, **15** to 1928, **26**.

VEGETABLE OILS

An extensive chapter on edible oils comparable with that on starch in Part I is not necessary, since physical and chemical values and the percentages of the glycerides in the oils are given under the seeds or fruits from which they are derived.

In some cases the analytical results reported are in the expressed oil and in others in the extracted oil, the method of preparation being stated so far as known. In general, the composition of the expressed oil differs little from that secured by extraction with ether. It is well known that refining causes changes in composition, but these are comparatively slight when the crude oil is freshly prepared from sound material.

Physical and Chemical Values.—The specific gravity is given at 15° or 15.5° C. When recalculated to these temperatures it has been by adding 0.00064 for each degree above 15° and subtracting the same figure for each degree below 15°.

Refractive indices are usually given at 25° C. for low solidifying point oils and at 40° C. for fats. In recalculated results the average correction of 0.000365 for each degree of temperature, as determined by Tolman and Munson,[1] was used, adding when above the desired temperature and subtracting when below. Although these corrections theoretically differ with the oil, for the purpose of showing the range of values the same correction for all seems sufficiently accurate.

Zeiss refractometer readings have been calculated to refractive indices, using the tables prepared by Winton[2] and reprinted among the Methods of the Association of Official Agricultural Chemists.

The method of determining the iodine number is not always stated. Results published prior to about 1900 were obtained by the Hübl method; since that time the Hanus and Wijs methods have come into use. Since 1903 when Munson and Tolman[3] studied these methods the Hanus method has been given the preference in the United States.

The solidification point of the insoluble fatty acids is designated "fatty acids, titer," since in nearly every instance practically all the fatty acids are insoluble.

[1] J. Am. Chem. Soc. 1902, **24**, 754.
[2] Connecticut Agr. Exp. Sta. Rep. 1900, p. 143.
[3] J. Am. Chem. Soc. 1903, **25**, 244.

Other values of the fatty acids are included only when they furnish data for the calculation of the percentages of constituent glycerides. The reader who desires further values is referred to the works of Lewkowitsch, Allen, and (in German) Ubbelohde.

Acid number and not acidity in terms of percentages of oleic acid is given throughout the tables. Whenever the results were expressed in the latter form they were recalculated by dividing by 0.5027. The reverse calculation, namely multiplying the acid number by the factor 0.5027, may be followed if the equivalent percentage of oleic acid is desired.

Composition.—The fatty acids and other constituents present in food fats are listed in the introduction to this volume. So far as possible the percentage composition of the different oils is expressed in terms of the different glycerides which, together with the unsaponifiable matter, add up to 100 or approximately that number.

Relation of Values to Composition.—The iodine number and, less accurately, the Maumené number (rise of heat with sulphuric acid) are measures of the degree of saturation of the fatty acids, the lower numbers corresponding to the higher degrees. The saponification number is a measure of molecular weight or the number of carbon atoms in the acid molecule, the lower figures in the same series corresponding to the higher molecular weights. Of the physical values, the specific gravity and refractive index are influenced by both factors; both increase with the decrease in saturation, but the specific gravity decreases with the increase of carbon atoms whereas the refractive index increases. The Reichert–Meissl number represents the water-soluble volatile acids, including all the butyric acid and small amounts of higher acids; the Polenske number represents the water-insoluble volatile acids, including variable amounts of caproic, caprylic, capric, lauric, myristic, and traces of higher acids.

Lewkowitsch classes as variables the acetyl number, the acid number, and the percentage of unsaponifiable matter of food oils since they do not fairly represent the amounts present in sound, fresh oils. The acetyl number is a measure of hydroxylated acids, but these occur in inconsiderable amounts in food oils.

The liquid (at 20° C.) fatty acids include the saturated acids butyric, valeric, caproic, and caprylic, and the unsaturated acids oleic, linolic, linolenic, and rapic.

Fatty acids may be combined, not only as triglycerides, but also as mixed glycerides in which two of the three bonds of the glycerin are saturated by one acid and one by another, or else all three are saturated by different acids

OIL CAKES

Although the residues from the manufacture of oil by extraction processes, because of the difficulty of completely removing the solvent, are suited only for use as fertilizers, the residues or cakes remaining after expressing edible oils are characterized by their high protein content which well entitles them to the name concentrated foods. Most of the cakes are used only for cattle foods; there are, however, a few notable exceptions. Cocoa is the powdered cake remaining after expressing cocoa butter, mustard flour is ground and bolted mustard cake, and almond and soy bean flour are analogous products much used as diabetic foods. Wesson, whose method of refining cottonseed oil is employed on a large scale by a corporation that bears his name, has recently perfected a process for manufacturing cottonseed flour that bids fair to rank with the oil as a nutritious human food.

The ground cakes from decorticated seeds marketed as cattle foods are commonly known as meals (cottonseed meal, linseed meal, peanut meal, etc.) and, when mixed with the hulls or other coarser parts, as feeds. Their sale in the United States is regulated by state and national laws that provide for fixing of standards of composition and official inspection.

Microscopic Examination of Oil Cakes and Meal.—Direct examination, although not so instructive as in the case of cereal products, serves to detect the starch of certain weed seeds and may show aleurone grains with original characters intact. When, as is often true, the cake is the residue from the hot process, it is well to proceed at once, after casual examination, to treatment: first, for removal of the oil with a suitable solvent such as gasolene, and second, for clearing the cell tissues. Digestion with diastase or boiling with dilute acid is obviously illogical if starch is absent; treatment with dilute sodium hydroxide is more useful, but for bleaching dark-colored tissues the following method is recommended:

Hebebrand's Method.—Chlorine gas is passed for several minutes into a mixture of 0.5 gram of the ground defatted material and 10 to 15 cc. of 7 per cent sodium carbonate solution. After dilution and settling, the deposit is examined. Soaking in Labarraque's solution accomplishes the same result.

NUTS OF THE PINE FAMILY

(*Pinaceæ*)

The naked ovules of the family ripen into seeds which, because of their hard spermoderm, are known as nuts. Pine nuts of the Old and New World and seeds of a Brazilian species of *Araucaria* are used as food. From the latter is prepared a commercial starch of local importance (Plate III, Fig. 30). Owing to the difficulty of securing authentic and unroasted material, only a limited number of species are here described, and the descriptions in some cases are incomplete.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *nuts* consist of a spermoderm, divided into a hard shell and inner skin, endosperm, and embryo with several cotyledons embedded in the endosperm. The European and Brazilian nuts are longer than those growing in the United States, which have further disadvantage of being thick-shelled.

COMPARATIVE MICROSCOPIC STRUCTURE.—Starch grains, aleurone grains, and oil drops are visible cell contents. So far as examined, the starch grains are largest (40 μ) in the Brazilian pine nut. In the European nuts they reach 20 μ, but in the species growing in the United States they seldom exceed 10 μ.

COMPARATIVE CHEMICAL COMPOSITION.—The kernels of the different species differ greatly in composition. The oil content usually exceeds that of all other constituents and is often several times the protein content. Starch is a minor constituent, at least in the species growing in Europe and the United States. Analyses of the Brazilian pine nut are not available.

PINE NUTS

Pinus spp.

Fr. Pomme de pin. Sp. Piñon. It. Pinocchio. Ger. Pineolen.

In Europe, pine nuts are obtained chiefly from *Pinus Pinea* L. (stone pine), less often from *P. Cembra* L. (Swiss pine), and are marketed shelled. Indians in the southwestern portion of the United States gather large quantities of nuts from *P. edulis* Engelm. for their own use and for shipment to the cities where they are sold unshelled on the streets. The

American species *P. cembroides* Zucc., *P. monophylla* Torr. et Frem., and *P. sabiniana* Douglas also produce edible nuts. Nuts are also gathered from Asiatic species.

MACROSCOPIC STRUCTURE.—Fig. 146 shows unshelled *nuts* from *P. Pinea* of Europe (I) and *P. edulis* of the United States (II to IV), also the pine nut of Brazil (V) obtained from a species of *Araucaria*. The European nut varies up to 25 mm. in length, the American up to 15 mm. Since the American nut is small and has a thicker outer spermoderm or shell (often over 0.5 mm.) it is inferior.

The outer spermoderm is light brown on one side and dark brown on the other side of the seed, and the inner spermoderm forms a thin brown skin over the kernel, the latter consisting of endosperm and central embryo. In the American species from six to twelve cotyledons, possibly more, are present.

Fig. 146.

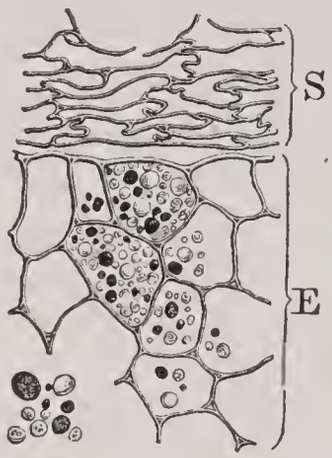


Fig. 147.

Fig. 146.—Pine Nuts: I *P. Pinea*; II–IV *P. edulis*; V *Araucaria*. *S* spermoderm; *E* endosperm; *R* radicle; *C* cotyledons. ×½. (A.L.W.)

Fig. 147.—Pine Nut. *S* spermoderm and *E* endosperm of *P. edulis* in cross section. Cell contents of *P. Pinea*, left, below. Starch grains, dark; aleurone grains, gray; oil drops, colorless. ×160. (K.B.W.)

MICROSCOPIC STRUCTURE (Fig. 147).—The outer spermoderm consists of (1) *outer epiderm* of polygonal, thick-walled, porous cells with red-brown contents on the dark side of the seed and (2) a mass of rounded *stone cells* with thick, porous walls and small lumen, containing very refractive, sometimes dark-colored contents.

A thin-walled collapsed tissue forms the *inner spermoderm* (*S*) except at the tip where the walls of the elongated cells are thicker, forming a cap.

Endosperm (*E*) and **Embryo** consist of thin-walled, characterless cells containing *starch grains*, *aleurone grains*, and *oil drops*, both cells and contents being smaller in the embryo.

The *starch grains* are rounded, seldom exceeding 10 μ, in the North American or 20 μ in the European nut but reaching 40 μ in the Brazilian pine (Plate III, Fig. 30). Young[1] notes the presence of both crystalloids and globoids in the aleurone grains.

Chief Structural Characters.—European nut up to 25 mm.; American nut up to 15 mm. with thicker outer spermoderm (shell). Both with thin inner spermoderm and multi-cotyledonous embryo in axis of endosperm.

Outer spermoderm with polygonal epidermal cells, some with red-brown contents and dense stone cell tissue; inner spermoderm of collapsed cells. Starch grains and aleurone grains larger in endosperm than in embryo and in European (20 μ) than in North American species (10 μ). In the Brazilian nut the starch grains reach 40 μ.

CHEMICAL COMPOSITION.—Schulze and Rongger[2] and Schulze[3] made exhaustive analyses of "Zirbelnüsse" or "Arvennüsse" from *P. Cembra*; Matthes and Rossié[4] and Maranis[5] analyzed pine nuts (piniolen) from *P. Pinea*, the stone pine of southern Europe; Yoshimura[6]

Composition of Pine Nut Kernels

	Kernel in nut	Water	Protein	Fat	N-f.ext.	Fiber	Ash
	%	%	%	%	%	%	%
P. Cembra: Schulze	38.0	0.0	19.4	59.4	17.2	1.2	2.8
P. Pinea: Matthes and Rossié		6.11	31.81	45.03	5.98*		
Maranis		4.9	37.5	51.6	4.8		1.2
P. koraiensis: Yoshimura		0.0	14.8	78.9	3.7		2.6
P. monophylla: Woods and Merrill	58.3	3.8	6.5	60.7	26.2		2.8
P. edulis: Woods and Merrill	59.4	3.4	14.6	61.9	17.3		2.8
P. sabiniana: Woods and Merrill	23.0	5.1	28.1	53.7	8.4		4.7

* Sugar calculated as sucrose.

[1] U. S. Dep. Agr., Bur. Chem. 1912, Bul. **160**, 28.
[2] Landw. Vers.-Stat. 1898, **51**, 189.
[3] Ibid. 1902, **57**, 57.
[4] Arch. Pharm. 1918, **256**, 289.
[5] Ibid. 1928, **266**, 121.
[6] Z. Unters. Nahr.-Genussm. 1910, **19**, 257.

worked on the nuts of *P. koraiensis*, belonging to the same group as *P. Cembra*; and Woods and Merrill in their monograph[1] give analyses of nuts (piñons) of three species growing west of the Rocky Mountains and Mexico.

In the air-dry skin, forming 1 per cent of the nut, and the water-free shell Schulze found respectively: water 10.3 and 0, protein 6.2 and 0.8, fat 12.4 and 1.2, total carbohydrates 69.3 and 97.2 (fiber 61.1, nitrogen-free extract 36.1), and ash 1.8 and 0.8 per cent.

Adams and Holmes[2] in air-dry nuts of *P. monophylla*, containing 7.88 per cent of water, found only 22.77 per cent of ether extract but 57.21 per cent of nitrogen-free extract.

Proteins.—Schulze and Winterstein[3] determined the hexone bases, and Abderhalden and Teruuchi[4] the mono-amino acids in the globulin of the Norway spruce (*Picea excelsa* Link = *Pinus excelsa* Lam. = *Pinus Abies* L.). Their combined results appear in the table below together with those of Yoshimura[5] on the globulin of the Korean pine (*P. koraiensis* Sieb. et Zucc.).

Amino Acids of Pine Nut Globulins

	P. excelsa	*P. koraiensis*
	%	%
Glycocoll	0.6	
Alanine	1.8	
Valine	present	
Leucine	6.2	11.40
Serine	0.1	
Aspartic acid	1.8	
Glutamic acid	7.8	2.70
Tyrosine	1.7	2.50
Phenyalanine	1.2	
Proline	2.8	
Tryptophane	present	
Arginine	10.90	7.05
Lysine	0.25	0.89
Histidine	0.62	0.53
	35.77	25.07

[1] Maine Agr. Exp. Sta. 1899, Bul. **54**.
[2] J. Ind. Eng. Chem. 1913, **5**, 285.
[3] Z. physiol. Chem. 1901, **33**, 547.
[4] Ibid. 1905, **45**, 473.
[5] Z. Unters. Nahr.-Genussm. 1910, **19**, 257.

Oil. *Physical and Chemical Values.*—Several coniferous oils have been examined by Grimme.[1] Of the authors named above who have made proximate analyses of the nuts, Matthes and Rossié, Maranis, Schulze, and Adams and Holmes have also examined the oil. Blasdale [2] examined the oil of *P. monophylla*, and Merrill [3] examined the oil of *P. edulis*.

Values of Pine Nut Oils

	Sp. gr. 15° C.	Refr. index 25° C.	Solidifying point	Saponification No.	Iodine No.
			° C.		
P. Cembra (Swiss pine):					
Grimme	0.9316	1.4764	−21	188	156.3
Schulze	.....	.....	.....	.....	156
P. Pinea (stone pine):					
Grimme	0.9326	1.4739	−22	192.6	120.9
Matthes and Rossié	0.9198	1.4732	−21	192.8	125
Maranis	0.9213	1.4719	.....	192	119
P. excelsa (Norway spruce):					
Grimme	0.9312	1.4778	−26	192	120.5
P. monophylla (piñon):					
Blasdale	0.9333	1.4769*	.....	192.8	101.3
Adams and Holmes	.....	1.4698	−15†	189.3	108.0
P. edulis (piñon):					
Merrill	0.9228	1.4641	.....	.....	105.8

* 15° C. (?). † Melting point.

In addition to the above figures Matthes and Rossié obtained the following: Reichert-Meissl number 0.8, Polenske number 0.6, Hehner number 94.81, and acetyl number 10.9.

Composition.—Adams and Holmes from their examination of the fatty acids of piñon oil conclude that it consists chiefly of the glyceride of oleic acid with small amounts of the glycerides of stearic, palmitic, lauric, and linolic acids.

Matthes and Rossié obtained the following figures on fatty acids in oil from *P. Pinea* in terms of percentage of the total acids:

	%
Stearic acid	0.4
Palmitic acid	5.1
Oleic acid	53.9
Linolic acid	40.6
	100.00

[1] Chem. Ztg. 1911, **35**, 925.

[2] J. Soc. Chem. Ind. 1896, **15**, 205.

[3] Maine Agr. Exp. Sta. 1900, Bul. **65**.

Phytosterol.—Schulze [1] found 0.40 per cent of phytosterol in the oil.

Lipase.—Nicolai [2] has studied the lipolytic activity of pine seeds during germination as shown by the carbon dioxide evolved from sodium carbonate by the liberated fatty acids.

Carbohydrates.—Schulze [3] found in the water-free nut of *P. Cembra* 9.3 per cent of water-soluble nitrogen-free substances including 6 per cent of *sugar*, 5.1 per cent of *starch*, and 2 to 3 per cent of *hemicellulose* including 1.5 per cent of *pentosans*. The hemicellulose yielded, on hydrolysis, galactose and xylose.

Phosphorus-Organic Compounds.—Schulze [3] found 1 per cent of *lecithin* and 1 per cent of *phytin* in the material mentioned in the preceding paragraphs. The lecithin contained 3.6 per cent of phosphorus.[4] Matthes and Rossié[5] found 0.048 per cent of lecithin phosphoric acid calculated as P_2O_5.

Enzymes.—*Lipase* is mentioned above.

Catalase is present in dead as well as live seeds, according to Vilmorin and Cazaubon;[6] hence it is not a factor in vitality.

Peroxidase occurs in pine seeds, according to Coupin.[7]

Mineral Constituents.—An analysis of the ash is also given by Schulze as follows:

K_2O	Na_2O	CaO	MgO	P_2O_5	SiO_2	Undeterm.
%	%	%	%	%	%	%
29.40	1.44	6.70	9.86	42.80	1.40	8.40

Minor Mineral Constituents. *Manganese.*—Kernel 36.4, shell 11.1 mg. per kilo dry basis (Quartaroli).[8]

Copper.—Kernel 51.7, shell 1.6 mg. per kilo, dry basis (Quartaroli).[8]

Zinc.—Kernel of *P. Pinea* 55.5 mg. per kilo, fresh basis (Bertrand and Benzon).[9]

[1] Loc. cit.
[2] Biochem. Z. 1926, **174**, 373.
[3] Loc. cit.
[4] Z. physiol. Chem. 1901, **52**, 54.
[5] Loc. cit.
[6] Compt. rend. 1922, **175**, 50.
[7] Ibid. 1925, **180**, 685.
[8] Ann. chim. appl. 1928, **18**, 47.
[9] Bul. soc. hyg. aliment. 1928, **16**, 457.

NUTS OF THE PALM FAMILY

(*Palmaceæ*)

WRITERS on tropical agriculture dwell on the variety of useful products obtained from members of this family. Of the four nuts (fruits) here classed with foods the cocoanut and palm nut also yield oil for soap-making, the ivory nut is primarily a technical product, and the cohune nut, although used now only for soap-making, can be refined for food.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *mesocarp* of the cocoanut and cohune nut is fibrous, of the palm nut oily, of the ivory nut saccharine. Stegmata or cells containing siliceous bodies occur on the fibers. A hard *endocarp* occurs in all four, but this is thin in the case of the ivory nut. Only one *seed* matures in the cocoanut, cohune nut, and palm nut, several in the ivory nut. A hard *endosperm* characterizes the ivory nut, a soft oily endosperm the other three species. Oil occurs in the endosperm of all four nuts but is abundant and available for pressing only in the cocoanut, cohune nut, and palm nut. All four nuts have minute embryos.

COMPARATIVE MICROSCOPIC STRUCTURE. *Endocarp.*—Stone cells of the usual type, in many rows, form the hard tissue of the cocoanut, cohune nut, and palm nut; curious funnel-shaped sclerenchymatized palisade cells in a single layer make up the inner shell of the ivory nut.

The *endosperm* cells of the cocoanut have thin, uniform walls; those of the palm nut, knotty-thickened walls; those of vegetable ivory enormously thickened, porous walls constituting the bulk of reserve material. Crystalloids of striking beauty occur in the cocoanut and palm nut.

COMPARATIVE CHEMICAL COMPOSITION.—Calculated to the dry basis, palm kernel and cocoanut flesh contain about 10 per cent of protein, 50 per cent of oil, and 13 per cent upward of nitrogen-free extract. The chief protein is a globulin. The oils of these as well as the cohune nut are characterized by the high saponification number (over 250), low iodine number (8 to 23), high Reichert-Meissl number (up to 8.3), and high Polenske number (up to 20). Glycerides of lauric

and myristic acids are the chief constituents, capric and in some cases caprylic and caproic acids also being present.

Ivory nut belongs in a widely different class from the oil seeds in that the shelled nut contains hardly more than 1 per cent of ether-soluble matter. The reserve material is largely in the cell walls but, inasmuch as the fiber on the average is less than 7 per cent and the nitrogen-free extract over 75 per cent, the bulk of the walls must be soluble in the acid and alkali used in the fiber determination.

PALM NUT

Elæis guineensis L.

Fr. Noix de palme. Sp. Nuez de palma. It. Noce di palma. Ger. Palmkern.

Two parts of the palm fruit yield commercial oils—the fruit flesh, the source of palm oil, and the endosperm, the source of palm nut oil.

Palm oil is edible when freshly prepared from good material, but the commercial oil is suited only for soap-making and other techincal purposes.

Palm nut oil is edible but is much less used than cocoanut oil, which it resembles in composition. Advantage has been taken of its deep orange-red color to give imitation butter, made chiefly of colorless fats, the appearance of the real without resorting to dyestuffs.

The tree is grown by natives on the west coast of Africa, who also make palm oil from the fruit flesh by crude processes and shell the nut before shipment to European or American centers where palm nut oil is pressed out from the endosperm.

MACROSCOPIC STRUCTURE.—Both in size and morphology the *nut*, which is a drupe, suggests a plum, but the oily mesocarp places it in the class with the olive and the avocado. Like the cocoanut it has a hard endocarp and a white oily endosperm, but the endocarp, which reaches over 6 mm. in thickness, is very dark colored and the endosperm nearly fills the seed cavity. The commercial shelled *seed* is irregular in shape, with one or more flattened sides, and varies up to over 2 cm. in length. The thin, black spermoderm is closely attached to the endosperm. Some of the seeds have fragments of the endocarp attached.

MICROSCOPIC STRUCTURE (Fig. 148). *Endocarp.*—The stone cells (*end*), like those of the cocoanut, are isodiametric or moderately elongated with yellow walls and dark contents.

Spermoderm (*S*).—In cross section the cells are nearly isodiametric; in tangential section they are elongated in different directions. They contain a deep brown substance.

Endosperm (*E*).—The cell walls are thicker than those of the cocoanut and appear to have knotty thickenings due to pores. These pores are best seen in walls at right angles to the optical axis.

As in the case of the cocoanut the ground substance of the *aleurone grains* (*al*) is not always evident, but the crystalloids (up to 25 μ) are beautifully distinct, especially after extraction with a fat solvent and mounting in glycerin iodine.

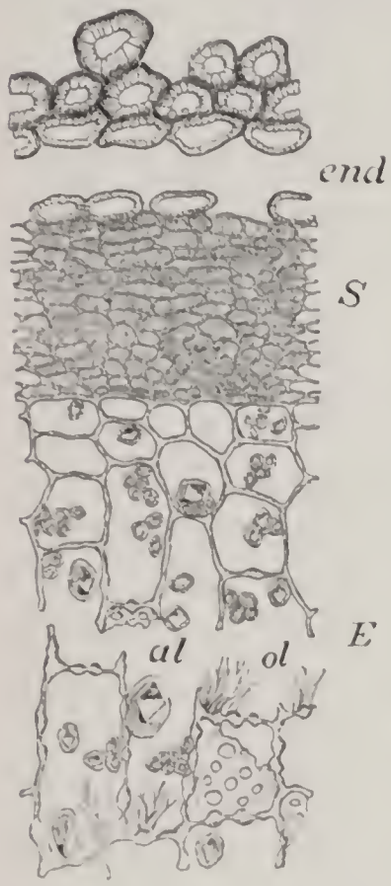


FIG. 148.—Palm Nut in cross section. *end* endocarp. *S* spermoderm. *E* endosperm: *al* aleurone grains, *ol* fat crystals. ×160. (A.L.W.)

In addition to oil drops, feathery crystals (*ol*) are often evident in glycerin mounts.

CHIEF STRUCTURAL CHARACTERS.—Fruit a small, oily drupe. Endocarp hard, thick, black; spermoderm thin, black; endosperm white, nearly filling cavity.

Endocarp stone cells similar to those of cocoanut. Spermoderm cells thin-walled, tangentially elongated. Endosperm with knotty-thickened walls; aleurone grains up to 25 μ, oil in drops, and fat in feathery crystals.

CHEMICAL COMPOSITION.—Fendler[1] gives the following percentages of fruit pulp, shell, and kernel in the whole fruit and of oil in the fruit pulp and the kernel, the percentages of shell being on the authority of Lommel.[2]

From these figures it is obvious that the production of oil from the pulp, known as palm oil, may be several times that from the kernel, known as palm nut oil.

Proteins.—Jones, Gersdorff, and Moeller[3] obtained 1.95 and 0.74 per cent for cystine and tryptophane respectively in palm nut protein.

	Minimum	Maximum
	%	%
Pulp	24	70
Shell	25	56
Kernel	9	25
Oil in pulp	46	66.5
Oil in kernel	43	50

[1] Real. Enz. Ges. Pharm. 1907, **9**, 713.
[2] Der Pflanzer, 1910, p. 290.
[3] J. Biol. Chem. 1924, **62**, 183.

Palm Oil.—Freshly and cleanly extracted palm oil is edible, but the product of native African labor, made by wasteful and unsanitary processes, is suited only for technical purposes and then only after refining. It is usually high in acid and of a disgusting odor.

Various authors call attention to the high acidity. The fresh oil contains usually at least 10 per cent of acids, calculated as oleic, which increases rapidly, often reaching 50 to 70 per cent and even higher. It is possible for all the fatty acids to become liberated, in which case the glycerides may be removed by washing.

Physical and Chemical Values are given below under Palm Kernel Oil.

Composition of Palm Oil.—Authorities disagree widely on the composition of both palm oil and palm kernel oil.

In the opinion of Brash [1] no acids other than oleic and palmitic occur in considerable amount and probably no acids of greater unsaturation than oleic. He found about 10 per cent of tripalmitin and triolein in neutral palm oil and palmito-distearin in hardened palm oil formed from palmito-diolein.

Rayner [2] on the other hand records 12 to 19 per cent of stearic acid in the solid acids and states that Armstrong and Allan found nearly 20 per cent. He found that the iodine number of the liquid acids varied from 99 to 109, corresponding to 10 to 20 per cent of linolenic acid.

McKinley [3] at the time of writing has the last word in the controversy. The oil examined was from Belgian Congo and had the following values: specific gravity 25°/25° 0.9146, refractive index at 25° C. 1.4578, saponification number 197.9, iodine number (Hanus) 53.7, Reichert-Meissl number 0.10, Polenske number 0.29, acetyl number 15.27, saturated acids 44.3 per cent, unsaturated acids 50.6 per cent, iodine number of unsaturated acids 99.9, acid number 20.65, and unsaponifiable matter 0.39 per cent. The percentages of the individual glycerides are as follows:

Composition of Palm Oil (McKinley)

Glyderides of:	%
Lignoceric acid	0.1
Stearic acid	5.2
Palmitic acid	40.8
Myristic acid	0.5
Oleic acid	47.2
Linolic acid	5.6
Unsaponifiable matter	0 39
	99.79

[1] J. Soc. Chem. Ind. 1926, **45**, 438T.
[2] Ibid. 1927, **46**, 160T.
[3] Oil Fat Ind. 1929, **6**, No. 6, 17.

Palm Kernel. *Composition of Kernels and Cake.*—A summary of 6 analyses of the shelled kernel reported by Dietrich and König,[1] Schädler,[2] and Emmerling,[3] also of 900 analyses of the cake, both whole and ground (palm cake meal), compiled by Dietrich and König, follow:

Composition of Palm Kernel and Cake

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Palm kernel:	6						
Min.		6.13	7.90	45.40	26.76	5.44	1.55
Max.		9.45	8.93	53.80	30.45	6.53	1.86
Aver.		8.40	8.41	48.75	26.87	5.82	1.75
Palm kernel cake:	900						
Min.		5.46	10.70	4.43	20.07	7.64	2.32
Max.		15.00	26.28	14.65	57.34	38.21	8.85
Aver.		10.09	16.20	10.98	37.38	21.45	3.90

A comparison of the figures in the foregoing table shows that the cake contains an excess of fiber due in part to imperfect removal of the shell.

Emmerling[3] confirms the statements of previous authors (Nördlinger, Rostock, and Dietrich and König) as to the high acidity of palm kernel cake and especially of the meal (ground cake). He found a range of 13.1 to 70 in the cake and of 8.9 to 86.6 in the meal, expressed in terms of percentages of the fat. The highest percentages were correlated with the lowest percentages of fat in the cake or meal.

Palm Kernel Oil.—The expressed oil varies in color from light yellow to brown-yellow. A grade selected because of its deep color has been used in butter substitutes. The acidity is well within 10 per cent, even for some time after pressing.

Values of Palm Oil and Palm Kernel Oil, as given in the following table, will serve as a general guide but, owing to the great variation in the oils and in some cases the paucity of results, should be regarded as tentative.

Ellis and Hall,[4] after making a large number of determinations of iodine number in expressed palm kernel oil by the Wijs method, find a range of 16 to 23. They state that the previously published values are

[1] Zusammens. Verd. Futterm. 1891, **1**, 578.
[2] Tech. Fette, 1883, p. 619.
[3] Landw. Vers.-Stat. 1898, **50**, 505.
[4] J. Soc. Chem. Ind. 1919, **38**, 128T.

VALUES OF PALM OIL AND PALM KERNEL OIL

	Sp. gr. 100°/15° C.	Ref. index 40° C.	Melting point	Saponification No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Fatty acids, titer
			°C.					° C.
Palm oil:								
Min.	0.857	1.4531	25	196	51	0.5	.....	35
Max.	0.860	1.4558	50	206	58	2.0	.....	45
Palm kernel oil:								
Min.	0.856	1.4494	23	242	10	4	6	20
Max.	0.874	1.4517	30	255	23	8	12	26

too low. They further state, however, that the extracted oil has a lower iodine number than the expressed oil.

Composition of Palm Kernel Oil.—Determinations of the percentages of fatty acids in palm kernel oil by Elsdon [1] and by Heiduschka and Burger [2] show wide differences as brought out in the following table:

COMPOSITION OF PALM KERNEL OIL

	Elsdon	Heiduschka and Burger
	%	%
Glycerides of:		
Stearic acid	7	trace ?
Palmitic acid	9	trace ?
Myristic acid	12	23.27
Lauric acid	55	51.96
Capric acid	6	5.00
Caprylic acid	5	2.50
Caproic acid	2	0.55
Oleic acid	4	16.72
	100	100.00

Mixtures corresponding to the above analysis of Heiduschka and Burger corresponded closely with the natural product.

[1] Analyst 1914, **39**, 78.

[2] Z. öffent. Chem. 1914, **20**, 361; see also Heiduschka, Z. angew. Chem. 1915, **28**, I, 304.

Pulp Oil of Various Palms.—Three varieties of *Elæis nigrescens* and two of *E. virescens* yield oils which, according to analyses by Hebert,[1] have values agreeing, except for unimportant exceptions, with those of palm oil.

Kernel Oil of Various Palms.—The oil of ten Brazilian palms has been examined by Teixera da Fonseca.[2] Seven of these have values agreeing closely with those of palm nut oil, namely, two of varieties of *Cocos syagrus*, two of species of *Astrocaryum*, and one each of *Acrocomia sclerocarpa*, *Maximiliana regia*, and *Attalea funifera*. Two samples were from varieties of *Elæis guineensis*, but the values were intermediate between those of typical palm oil and palm kernel oil (saponification number 231.4 and 220.2; iodine number 25.5 and 31.6) although probably seed oils. One, from *Œnocarpus bataua* (patassa), had values which were not even intermediate between those of palm and palm kernel oils but were beyond the limits of the former (saponification number 191.8; iodine number 78.2).

COHUNE NUT

Attalea Cohune Mart.

The nut of the cohune palm is a product of Honduras. Although the oil is now used for soap-making it can be refined for food purposes.

MACROSCOPIC STRUCTURE.—The *nut* resembles a diminutive cocoanut and the kernels are separated with difficulty from the hard pericarp.

MICROSCOPIC STRUCTURE.—No data available.

CHEMICAL COMPOSITION. Proteins.—Johns and Gersdorff[3] obtained 20.63 per cent of protein in the press cake. The *globulin* precipitated from the brine extract with ammonium sulphate resembles that of the cocoanut.

Amino Acids of Cohune Globulin.—The globulin contained, according to Johns and Gersdorff:

	%
Cystine	0.81
Arginine	17.17
Lysine	7.42
Histidine	1.72

Jones, Gersdorff, and Moeller[4] found in the globulin: cystine 2.17 and tryptophane 0.65 per cent.

[1] Mat. Grasses 1912, **4**, 2171.
[2] Int. Rev. Sci. Prac. Agr. 1922, **1**, 395; Chem. Abs. 1923, **17**, 3616.
[3] J. Biol. Chem. 1920, **45**, 57.
[4] Ibid. 1924, **62**, 183.

The *Nitrogen Distribution* of the globulin as obtained by Jones and Gersdorff was: amide nitrogen 7.5, humin nitrogen adsorbed by lime 0.84, humin nitrogen in amyl alcohol extract 0.11, cystine nitrogen 0.53, arginine nitrogen 30.87, histidine nitrogen 2.61, lysine nitrogen 7.94, amino nitrogen of filtrate 47.87, and non-amino nitrogen of filtrate 2.28 per cent.

Fat (Oil).—The nut as examined by Bray and Elliott [1] contained 4.5 per cent of water and 65.4 to 71.6 per cent of fat. The values of the oil found by them differ little from those of palm kernel, being as follows:

	Sp. gr. 100°/15° C.	Melting point	Saponification No.	Iodine No.	Reichert-Wollny No.	Polenske No.	Fatty acids, titer	Unsaponifiable matter
		° C.					° C.	%
Min...	0.868	22	252.4	11.0	6.8	12.5	19.7	0.2
Max...	0.871	24	256.5	13.7	8.3	15.4	21	0.3

COCOANUT

Cocos nucifera L.

Fr. Coco. Sp. Coco. It. Cocco. Ger. Kokosnuss.

For centuries one of the most important products in the tropics, the cocoanut of late years has entered on a large scale into the world's commerce. No other nut is so extensively used in domestic cookery or, with the exception of the peanut, as an ingredient of confectionery. Shredded cocoanut for these purposes is sold desiccated or canned. From the dried meat, known as copra, are obtained cocoanut oil, much used in the manufacture of butter and lard substitutes as well as soap, and cocoanut cake, a by-product that ranks among the most concentrated of cattle foods. Coir fiber from the pericarp is utilized in making mats, matting, and cordage and for calking. Only one by-product has lost prestige, namely cocoanut shells, many tons of which were formerly ground for adulterating spices.

Opinions differ as to the original home of the tree, some favoring Asia, others Malaysia. In any event the nut lends itself to dissemination by tides and ocean currents and man was not a necessary agent. Today the Philippine Islands stand foremost in the production of cocoanuts and copra.

[1] Analyst 1916, **41**, 298.

MACROSCOPIC STRUCTURE.—A striking character of the inflorescence is the long, dense spike of *staminate flowers*, with a single *pistillate flower* at the base, enclosed in a spathe. The three-ovuled, three-celled ovary develops into a one-celled, one-seeded *fruit*, but the triangular shape, the longitudinal ridges on the nut, and the three germinating eyes at the base belong to the three original carpels.

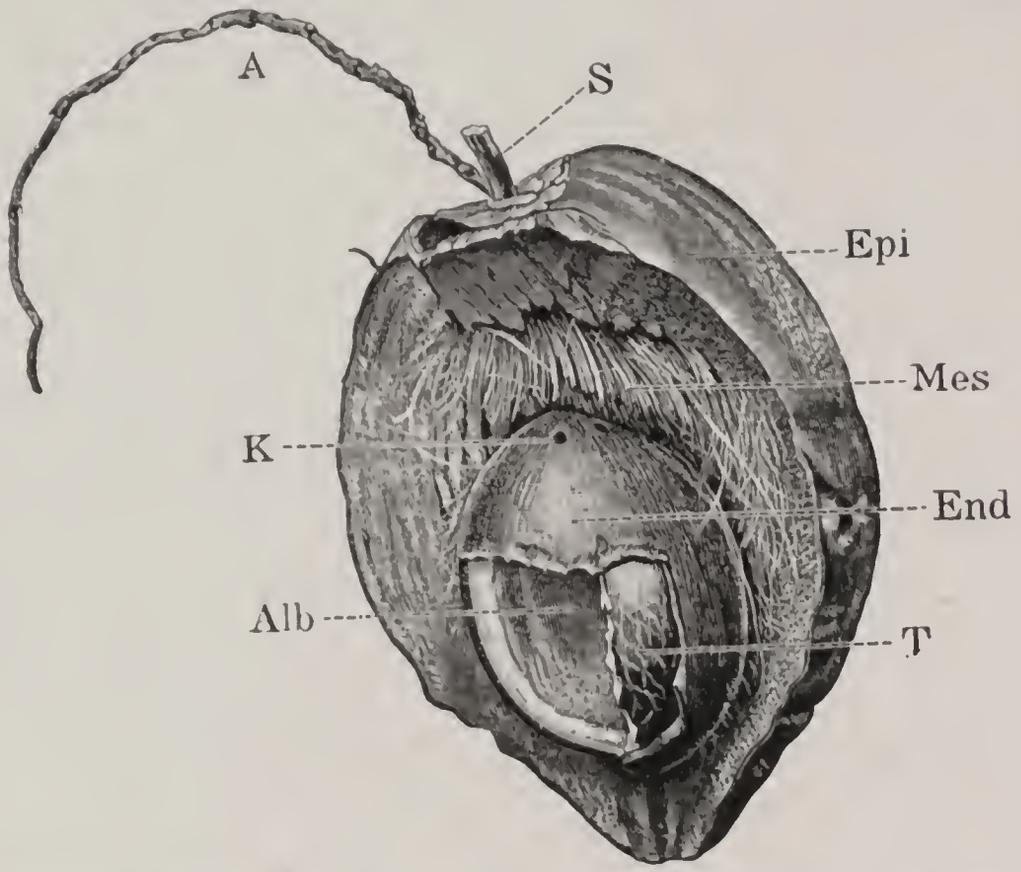


FIG. 149.—Cocoanut Fruit. Axis: *S* lower part forming stem, *A* upper end with scars of staminate flowers. Pericarp: *Epi* epicarp, *Mes* fibrous mesocarp, *End* hard endocarp (shell). *T* inner spermoderm adhering to endosperm. *Alb* endosperm about cavity of nut. *K* germinating eye. $\times 1_{5}$. (A.L.W.)

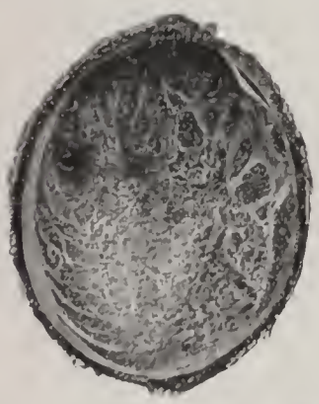


FIG. 150.—Cocoanut. Inner surface of shell with adhering outer spermoderm. Raphe and branches at left. $\times 1_{5}$. (A.L.W.)

The *fruit* (Figs. 149 and 150) is somewhat larger than a man's head and has a blunt-pointed tip. The tough epicarp (*Epi*), the mass of fibrous tissues forming the mesocarp (*Mes*), the hard brown, woody shell or endocarp (*End*), several millimeters thick, the thin, soft spermoderm (*T*), and the endosperm (*Alb*) are closely united, but the epicarp and most of the mesocarp are cut away before shipment of the nuts, and the shell down to the raphe and its numerous branches is broken away before eating or preparing copra, thus removing all inedible tissues.

The minute *embryo* is located beneath one of the eyes, through which it protrudes on sprouting.

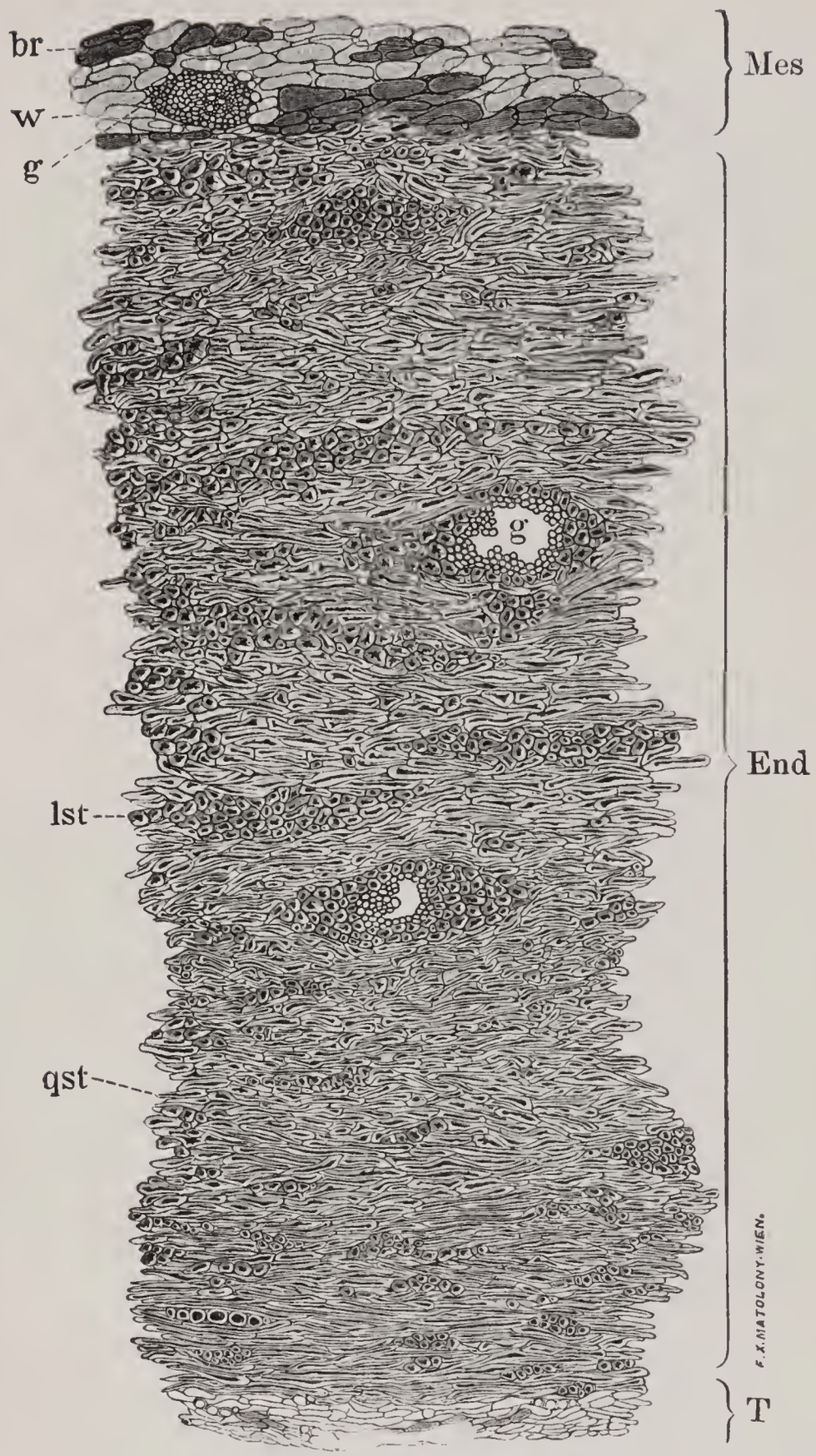


FIG. 151.—Cocoanut. Shell in cross section. *Mes* adhering mesocarp: *br* brown parenchyma, *w* colorless parenchyma, *g* vascular bundle. *End* endocarp: *lst* longitudinally elongated and isodiametric stone cells, *qst* transversely elongated stone cells, *g* vascular bundle. *T* adhering outer spermoderm. ×60. (A.L.W.)

The *milk* which is at first present gradually solidifies to form the endosperm.

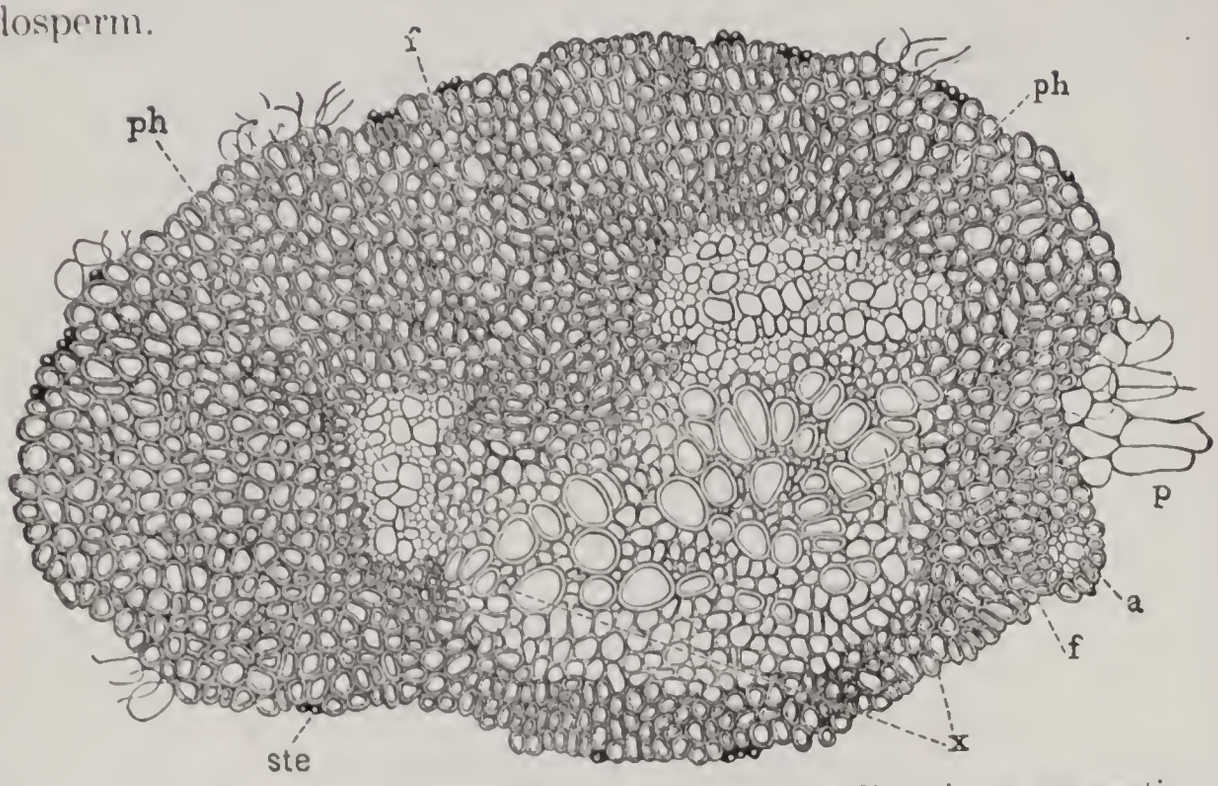


FIG. 152.—Cocoanut. Large flattened mesocarp fiber in cross section. *ste* stegmata; *f* sheath of bast fibers; *ph* two phloem groups; *x* xylem; *p* parenchyma of ground tissue; *a* small rudimentary vascular bundle. ×90. (A.L.W.)

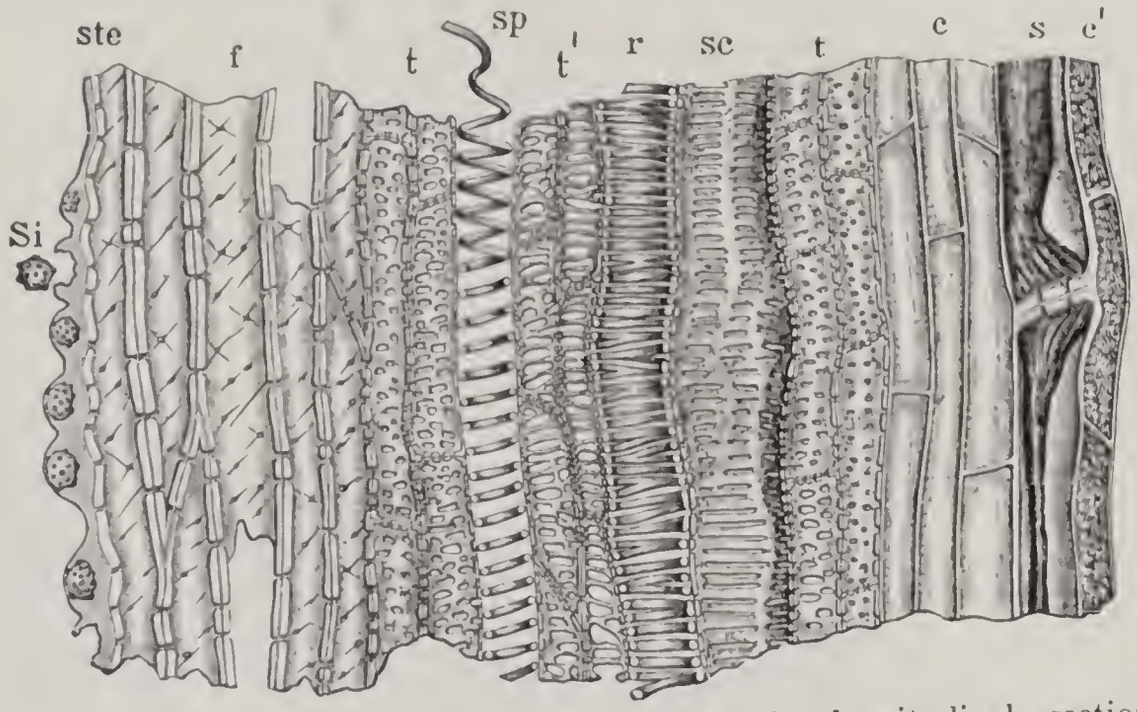


FIG. 153.—Cocoanut. Large mesocarp fiber in longitudinal section. *ste* stegmata; *Si* silicious body; *f* bast fibers; *t* tracheids with small pits; *t'* tracheids with large pits; *sp* spiral vessel; *r* reticulated vessel; *sc* sclariform vessel; *s* sieve tube; *c* cambiform cells; *c'* companion cells. ×300. (A.L.W.)

MICROSCOPIC STRUCTURE.—Hanausek [1] and later authors describe the endosperm; Winton [2] describes the endocarp.

[1] Nahr. u. Genussm. Kassel, 1884, p. 155. Mic. Tech. Products. New York, 1916, p. 404.

[2] Am. J. Sci. 1901, **12**, 265.

Pericarp.—The *mesocarp* or fibrous mass differs from the endocarp or shell largely in that the ground tissue is of thin-walled parenchyma (Fig. 151, *br*, *w*) instead of stone cells. A brown substance often impregnates the tissues.

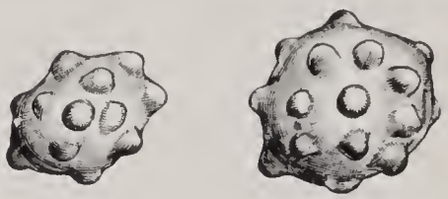


Fig. 154.—Cocoanut. Siliceous bodies from stegmata of a fiber. ×1500. (A.L.W.)

The *fibers* (Figs. 152, 153 and 154) have a thick sheath of bast fibers (*f*) with *stegmata* (*ste*) here and there on the surface, each containing a warty siliceous body (*Si*) up to 12 μ in diameter. The vascular bundle is double with the two phloem groups (*ph*) well separated by bast fibers and the xylem groups (*x*) combined to form one. In the latter are a variety of vessels (trachæ) and jointed, pitted elements (tracheids).

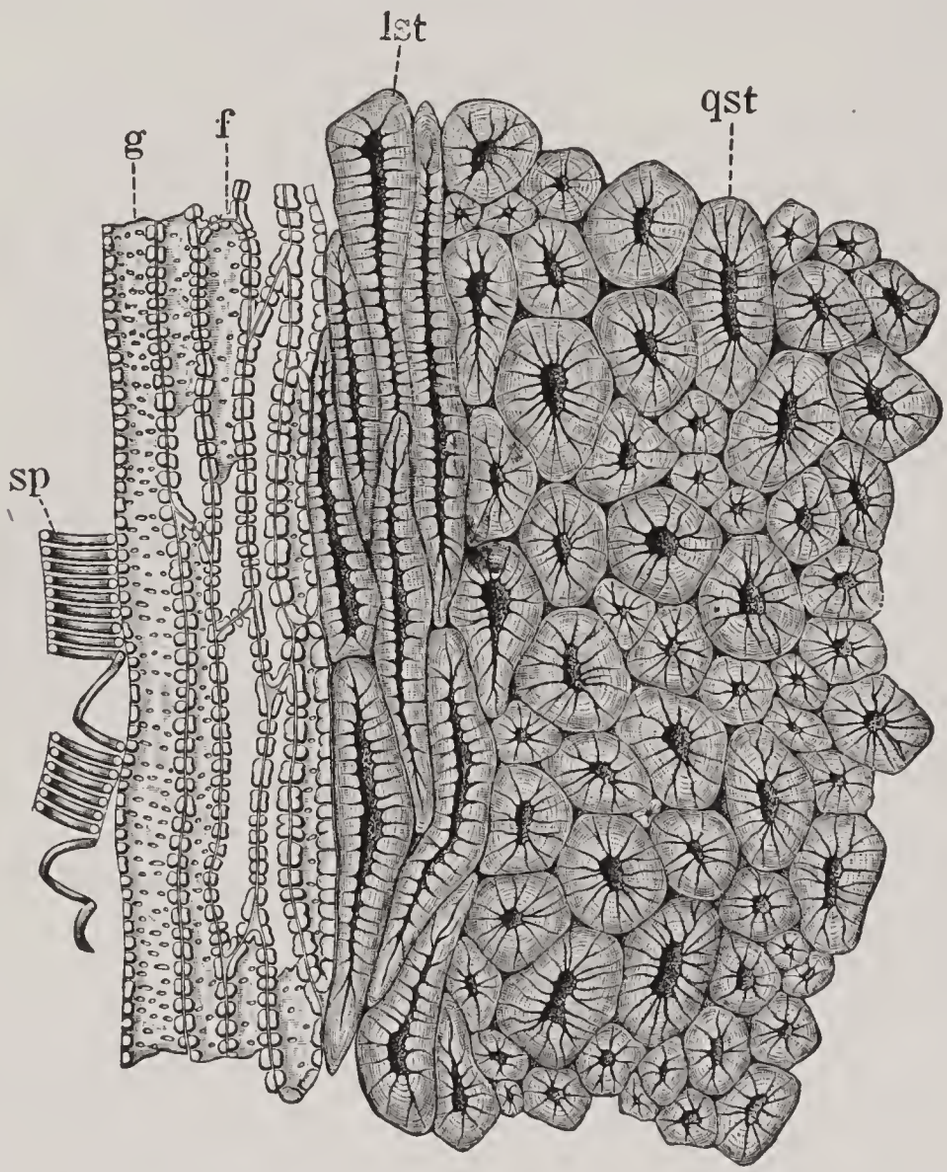


Fig. 155.—Cocoanut. Shell in radial-longitudinal section. *sp* spiral vessel, *g* pitted vessel, and *f* thick-walled porous cells of vascular bundle; *lst* longitudinally elongated stone cells; *qst* transversely elongated and isodiametric stone cells. ×300. (A.L.W.)

Endocarp (Figs. 151, 155 and 156).—Characteristic of the stone cells (*lst*, *qst*) are their yellow walls and dark brown contents, also their frequent

elongation and arrangement in groups, those in the same group being extended in the same direction.

Spermoderm (Fig. 151, *T*; Fig. 157; 158, *S*).—In the *outer spermoderm* the cells are large, elongated in various directions with porous walls of medium thickness; in the *inner spermoderm* they are small and non-porous.

Endosperm (Fig. 158).—Cells of the *outer endosperm* (E^1), making up two or three layers, are isodiametric; those of the *inner endosperm* (E^2) are large and radially elongated. Throughout *oil* (ol^1) or *crystalline fat* (ol^2) and *aleurone grains* with crystalloids (*al*) are the visible cell contents.

Whether the fatty matter is *oil* or *fat* depends in some degree on the temperature. When sufficiently warm only oil drops are visible; when

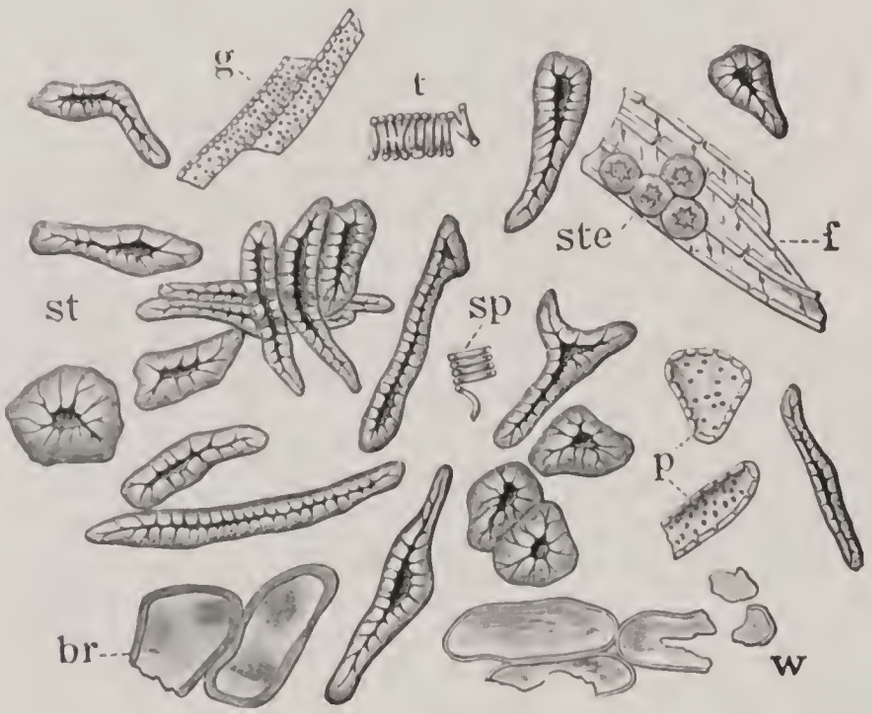


Fig. 156.—Cocoanut. Ground Shells. Mesocarp: *br* brown parenchyma, *w* colorless parenchyma. Endocarp: *st* stone cells, *t* reticulated vessel, *sp* spiral vessel, *g* pitted vessel, *f* bast fiber with *ste* stegmata. Spermoderm: *p* porous cells. ×160. (A.L.W.)

cool, masses with radiating crystals are seen. With proper conditions the same mount may contain both, that is, crystals and mother liquor, the two being doubtless of different composition.

The *crystalloids*, like those of the potato, are of beautiful form with no distinct outer coat or ground substance. They vary from minute up to 25 μ or over. On dissolving the fat in ether the protein matter is left in the form of a network or groups resembling aggregates of rice starch. Hanausek's view that small crystalloids occur with large in the same grain and Hartwich's that crystalloids and globoids are both

present need verification. The close proximity of small grains to large might lead to the erroneous interpretation that they occur in the same grain.

Chief Structural Characters.—Nut large, hollow, with milk when fresh. Mesocarp fibrous; endocarp hard, brown; spermoderm thin; endosperm white, oily; embryo minute.

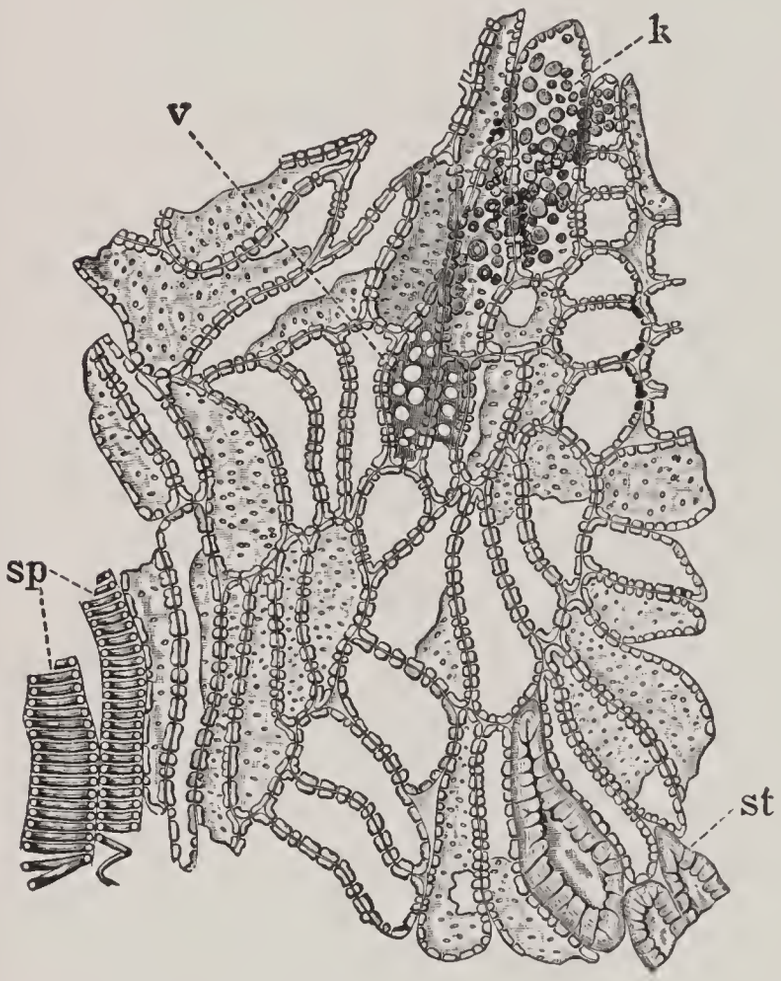


Fig. 157.

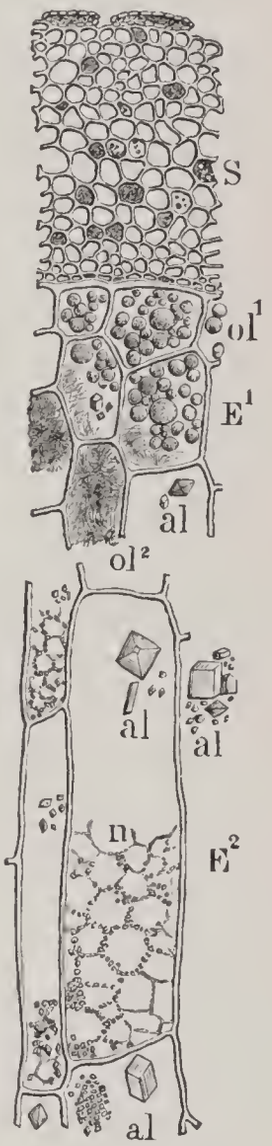


Fig. 158.

Fig. 157.—Cocoanut. Outer spermoderm in tangential section. *sp* spiral vessels; *k* globular and *v* film-like cell contents; *st* stone cells. ×300. (A.L.W.)

Fig. 158.—Cocoanut. *S* inner spermoderm, E^1 outer and E^2 inner endosperm in cross section. ol^1 oil; ol^2 crystalline fat; *al* crystalloids; *n* network after dissolving oil in ether. ×160. (A.L.W.)

Mesocarp and endocarp with double vascular bundles in parenchyma and stone cell ground tissue respectively; vascular bundles with stegmata, bast fiber sheath, and two groups of phloem. Outer spermoderm of large porous cells; inner spermoderm of small non-porous cells. Outer endosperm of small isodiametric cells; inner endosperm of large, radially elongated cells; contents oil drops or radiating fat crystals or

both and aleurone grains with large and small crystalloids in indistinct ground substance.

CHEMICAL COMPOSITION.—The literature prior to 1902 is fully covered in a monograph entitled "Chemical Studies of the Cocoanut with some Notes on the Changes during Germination" by Kirkwood and Gies,[1] free use of which has been made in the following pages.

Percentages of Parts.—Determinations have been made by Von Ollech (König)[2] and Bachofen[3] with results as follows:

	Husk	Shell	Kernel	Milk
	%	%	%	%
Von Ollech	30.45	19.59	37.78	12.18
Bachofen	57.28	11.59	18.54	12.58

Husked nuts from Jamaica and the New York market were separated into their parts by Kirkwood and Gies with the following results:

	Samples	Shell	Kernel	Milk	Sp. gr. of milk
		%	%	%	
Jamaica:	21				
Min	.....	23.5	48.2	8.2	1.014
Max	.....	32.8	62.0	25.1	1.037
Aver	.....	**27.8**	**55.2**	**17.0**	**1.023**
New York market:	12				
Min	.....	23.1	48.8	7.3	1.015
Max	.....	32.9	63.3	27.0	1.034
Aver	.....	**27.1**	**55.1**	**17.8**	**1.021**

Composition of Cocoanut Products.—Determinations of the solids and ash in the milk and the kernels of 18 samples of Jamaica nuts with a range of specific gravity of the milk of from 1.016 to 1.028, by Kirkwood and Gies,[1] follow:

[1] Bul. Torrey Bot. Club, 1902, **29**, 321.
[2] Mensch. Nahr.-Genussm. 1893, **2**, 495.
[3] Queensland Agr. J. Apr. 1900.

	Water	Organic matter	Ash
	%	%	%
Milk:			
Min	94.62	3.82	0.41
Max	95.73	4.78	1.02
Aver	**95.23**	**4.21**	**0.56**
Kernel:			
Min	42.10	46.61	0.90
Max	52.29	59.46	1.11
Aver	**46.31**	**52.66**	**1.03**

In the table below, the analyses of unripe and ripe cocoanut milk by Van Slyke [1] show the transition from glucose to sucrose on ripening. Other analyses of milk from ripe nuts are by Hammerbacher [2] and Woods and Merrill.[3] Benre [4] obtained figures for the usual proximate constituents in 3 samples of the milk in harmony with those of the foregoing authors and in addition phosphoric acid 0.05 to 0.18 and chlorine 0.16 to 0.22 gram per 100 cc.

The analyses of the kernel by Woods and Merrill are of fresh nuts although they appear to have been dried preliminary to analysis. The figures given by König for copra are the averages of early analyses; recent analyses are not available, which seems remarkable in view of the great economic importance of the product. The range in fat of 21 analyses of kiln- and hot air-dried copra from various regions, as given by Schindler and Waschata,[5] is 64.47 to 74.72 per cent.

The shredded cocoanut analyzed by Atwater and Bryant [6] represents the desiccated preparation used for confectionery and pastries, now largely replaced by the moist tinned product.

Lastly the analyses of the cake, quoted by Dietrich and König,[7] and the analysis by Caray [8] of the meal or ground cake, obtained by the expeller process, show the composition of the products used for feeding.

[1] Chem. Centralbl. 1891, **1**, 595.
[2] Landw. Vers.- Stat. 1875, **18**, 472.
[3] Maine Agr. Exp. Sta. 1899, Bul. **54**.
[4] Pharm. Centralh. **47**, 1046.
[5] Chem. Rev. 1905, p. 169.
[6] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.
[7] Zusammens. Verd. Futterm. 1891, p. 723.
[8] Phil. Agr. 1921, **10**, 55.

Composition of Cocoanut Products

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Milk from unripe nuts:						
Van Slyke	95.01	0.13	0.12	4.11*	0.0	0.63
Milk from ripe nuts:						
Van Slyke	91.23	0.29	0.15	7.27†	0.0	1.06
Hammerbacher	91.50	0.46	0.07	6.78	0.0	1.19
Woods and Merrill	92.7	0.4	1.5	4.6	0.0	0.80
Kernel:						
Kirkwood and Gies	46.31	4.08‡	37.29	7.90	3.39	1.03
König (copra)	5.81	8.88	67.00	12.44	4.06	1.81
Woods and Merrill	14.1	5.7	50.6	27.9		1.70
Shredded cocoanut:						
Atwater and Bryant	3.5	6.3	57.4	31.5		1.3
Cocoanut cake:						
Dietrich and König						
Min	5.49	10.36	2.43	26.71	5.65	2.68
Max	19.55	29.73	23.04	50.78	28.30	9.45
Aver	**10.66**	**19.06**	**11.05**	**41.06**	**14.12**	**4.05**
Cocoanut meal:						
Caray	11.19	20.94	14.13	34.53§	13.82	5.39

* Glucose 3.97 per cent, sucrose none.

† Glucose trace, sucrose 4.42 per cent.

‡ N×5.5.

§ Carbohydrates 24.90, water-soluble free organic acids as oleic 7.07 per cent.

Proteins.—The only protein present in cocoanut endosperm in considerable amount is a *globulin*, the *conglutin* of Ritthausen,[1] and the *phytovitellin* of Chittenden and Setchell.[2] Kirkwood and Gies,[3] who regard this protein as an *edestin*, have prepared it in crystalline form. A photomicrograph of their preparation shows mostly rhombohedral forms although they state that octahedra usually predominate. They further found that the globulin contained 18.24 per cent of nitrogen and 1.84 per cent of ash. Ritthausen found 17.8 and 17.9 per cent of nitrogen and Chittenden and Setchell 18.40 per cent.

A *proteose* obtained by Kirkwood and Gies from the globulin filtrate contained 18.53 per cent of nitrogen and 1.33 per cent of ash.

Jones, Gersdorff, and Moeller[4] obtained in cocoanut globulin the following: cystine 1.54 and tryptophane 1.25 per cent.

Amino Acids of Cocoanut Globulin.—The products of hydrolysis of cocoanut globulin, as determined by Johns and Jones and by Jones and

[1] Pflüger's Arch. 1880, **21**, 81.

[2] Chittenden: Digestive Proteolysis, 1895, p. 32.

[3] Loc. cit.

[4] J. Biol. Chem. 1924, **62**, 183.

Johns [1] together with the results of Johns, Finks, and Gersdorff [2] on cystine and basic amino acids, appear in the table below:

Hydrolysis Products of Cocoanut Globulin (Jones et al.)

	%
Alanine	4.11
Valine	3.57
Leucine	5.96
Serine	1.76
Cystine	1.44
Aspartic acid	5.12
Glutamic acid	19.07
Tyrosine	3.18
Phenylalanine	2.05
Proline	5.54
Trytophane	+
Arginine	15.92
Lysine	5.80
Histidine	2.42
Leucylvaline anhydride	0.64*
Ammonia	1.57
	78.15

* Dakin's butyl alcohol method.

Nitrogen Distribution in Cocoanut Globulin.—Johns, Finks, and Gersdorff,[2] employing Van Slyke's method, determined the nitrogen distribution in cocoanut globulin with the following results in percentages of the total nitrogen: amide nitrogen 7.99, humin nitrogen absorbed by lime 1.41, humin nitrogen in amyl alcohol extract 0.11, cystine nitrogen 0.96, arginine nitrogen 29.5, histidine nitrogen 3.68, lysine nitrogen 6.41, amino-nitrogen of filtrate 45.44, and non-animo nitrogen of filtrate 4.6 per cent. The free animo-nitrogen was nearly half the lysine nitrogen.

Oil.—The wide gap between the cocoanut palm and its near relative the oil palm on the one hand and the common exogenous plants yielding commercial oils on the other is exemplified by the radical differences in the nature, values, and composition of the fats.

Cocoanut oil seems an inappropriate name for cocoanut fat, as in temperate regions it is usually solid. Cocoa butter, a name appropriated by cacao fat, rightfully belongs to cocoanut oil since it approaches butter in physical and chemical characteristics.

Physical and Chemical Values.—The following range of values, compiled from various sources, distinguishes sharply cocoanut oil from

[1] J. Biol. Chem. 1920, **44**, 283, 291.

[2] Ibid. 1919, **37**, 149.

common vegetable and animal oils, excepting palm nut oil and other oils and fats of the palm family:

	Sp. gr. 100°/15°	Refrac. Index. 40° C.	Melting point	Saponification No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Fatty acids, titer
			° C.					° C.
Min...	1.863	1.4475	20	250	8	6	15	21
Max...	1.874	1.4495	27	265	10	8	20	26

Composition.—Cocoanut oil consists largely of fatty acids of low molecular weight (hence its high saponification number) and high saturation (hence its low iodine number). It further simulates, in a degree, butter fat in containing a considerable amount of volatile fatty acids soluble in water, as shown by a higher Reichert-Meissl number than vegetable fats of other groups. The relatively high Polenske number, representing volatile insoluble acids, which is a measure of the content of myristic and lauric acids, is characteristic of both cocoanut and palm kernel oils, distinguishing them from butter fat as well as other vegetable fats and oils.

In addition to myristic and lauric acids, Bömer and Baumann [1] demonstrated the presence of palmitic, stearic, oleic, and caprylic acids but did not find caproic and capric acids, formerly thought to be present. They state that the glycerides of the saturated fatty acids consist in large part of a caprylo-lauro-myristin, a myristo-dilaurin, and a lauro-dimyristin, the melting points being respectively 15°, 33°, and 38.1° C. Very small amounts of a palmito-dimyristin and a stearo-dipalmitin, melting respectively at 45° and about 55° C., are also present.

Expressed and Extracted Oils have practically the same composition, as shown by the following figures reported by Merrill.[2]

	Sp. gr. 24° C.	Refrac. index 20° C.	Iodine No.
Expressed oil	0.9223	1.4553	6.27
Ether-extracted oil	0.9228	1.4550	6.17

[1] Z. Unters. Nahr.-Genussm. 1920, **40**, 97.

[2] Maine Agr. Exp. Sta. 1900, Bul. **65**.

Carbohydrates.—De Kruijff [1] states that the milk of the young nut contains sucrose which is inverted by the enzyme sucrase during ripening, also that the mature nut contains oxidase and catalase.

Dunstan [2] found sucrose 0.1 per cent, glucose 0.9 per cent, and mannitol 1.8 per cent in cocoanut milk ("water") evidently from quite immature nuts as the milk of ripe nuts contained sucrose 2.6 per cent and glucose 0.5 per cent but no mannitol.

Lahille,[3] agreeing with Van Slyke (see analyses above) and Dunstan but not with De Kruijff, found sucrose in the milk of the mature, not the young, nut.

Ripening Changes are grouped by Gonzalez y Sioco [4] into three periods: (1) before the formation of the endosperm when invert sugar and amino acids accumulate in the milk, (2) when the loss of water from the nut takes place and sucrose appears in the milk, and (3) when a sudden rise in the oil content of the endosperm and a loss of nutrients in the milk occur.

Caray,[5] supplementing his analytical studies mentioned above, has isolated from dried copra meal sucrose, raffinose, galactose, fructose, and glucose, and from the milk sucrose, fructose, and glucose. As proof he shows photomicrographs of the sugars. Following are the percentages found:

Carbohydrates of Dried Copra Meal (Caray)

	%
Sucrose	14.33
Raffinose	2.42
Galactose	2.42
Pentoses	2.40
Fructose	1.20
Glucose	1.19
Cellulose	15.55
Pentosans	2.22
Starch	0.87
Dextrin	0.58
Galactan	0.50
	43.68

Mineral Constituents.—Both Hammerbacher [6] and Bachofen [7] have analyzed the ash of the kernel and of the milk, and in addition Bachofen

[1] Bul. Dept. Agr. Indes Néerland 1906, p. 1; Abs. Exp. Sta. Rec. 1907, **18**, 826.
[2] Trop. Agr. Mag. Ceylon Agr. Soc. 1906, **26**, 377; Abs. Exp. Sta. Rec. **18**, 338.
[3] Bul. écon. Indochine, n. ser. 1920, **23**, 1; Abs. Exp. Sta. Rec. **45**, 507.
[4] Phil. Agr. Forest. 1914, **3**, 25.
[5] Phil. Agr. 1924, **13**, 229.
[6] Loc. cit. [7] Loc. cit.

has analyzed the ash of the husk and of the shell. The latter analyst gives his results for chlorine in terms of sodium chloride in the case of the husk and shell and in terms of sodium and potassium chlorides in the case of the kernel and milk, but the writers have recalculated these results in order to make them comparable with those of Hammerbacher.

Ash Analyses of Parts of Cocoanut

	Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3 †	P_2O_5	SO_3	SiO_2	Cl	O ‡
	%	%	%	%	%	%	%	%	%	%	%
Hammerbacher:											
Kernel.....	0.97	43.88	8.39	4.63	9.43	.....	16.99	5.09	0.50	13.42	3.02
Milk.....	1.9	55.20	0.73	3.68	6.61	.....	20.51	5.23	.....	10.37	2.34
Bachofen:											
Husk.....	1.63	30.71	27.56	4.14	2.19	0.54	1.92	3.13	8.22	27.88	6.30
Shell.....	0.29	45.01	23.67	6.26	1.32	1.39	4.64	5.75	4.64	9.44	2.13
Kernel.....	0.79	54.06	2.66	3.10	1.98	0.59	20.33	8.79	1.31	9.25	2.08
Milk.....	0.38	34.57	13.96	7.43	3.97	trace	5.68	3.94	2.95	35.52	8.02

* In part ashed. † Includes Al_2O_3. ‡ Equivalent to Cl.

Lahille[1] believes that the potash exists in the milk as nitrate and chloride.

Minor Mineral Constituents. *Zinc.*—Endosperm 10, milk 0 mg. per kilo, air-dry basis (Bertrand and Benzon).[2]

IVORY NUT

Phytelephas spp.

Fr. Corozo. Sp. Marfil vegetal. It. Avorio vegetale. Ger. Elfenbeinnuss.

True vegetable ivory is the endosperm of several species of *Phytelephas* while the so-called Polynesian ivory nuts are produced by two species of *Cœlococcus.*[3] Most of the commercial product is obtained from *Phytelephas macrocarpa* R. et P.

Although used primarily for making buttons, the refuse, ground and roasted, has been used as a coffee substitute, and finely ground has value for feeding farm animals.

The nut is here classed as an oil seed as it is non-starchy and contains oil and protein, but it more properly belongs in a special class because of the rich store of carbohydrate in the thickened walls. Other products with reserve material chiefly in the cell walls are the coffee berry, date stone, and persimmon seed.

[1] Loc. cit.

[2] Bul. soc. hyg. aliment. 1928, **16**, 457.

[3] Hanausek-Winton: Mic. Tech. Prod. New York, 1907, pp. 411–414.

MACROSCOPIC STRUCTURE.—In general structure, the large *fruit* differs from the cocoanut and palm fruit in that it is six- to seven-seeded and the mesocarp is edible and saccharine, not fibrous or oily. Only the *nuts*, consisting of endocarp and seed, enter the world commerce. Each is the size of an egg but in shape suggests the segment of an orange. At the base it bears an excrescence resembling half of a peach pit. The shell, consisting of "endocarp" and outer spermoderm, is brittle, dull gray on the surface, but dark brown after scraping, and usually less than 1 mm. thick. The *kernel* is loose in the shell and consists of inner spermoderm and a dense mass of horn-like endosperm with a small slit-like cavity in the middle. The minute embryo lies beneath the excrescence of the nut.

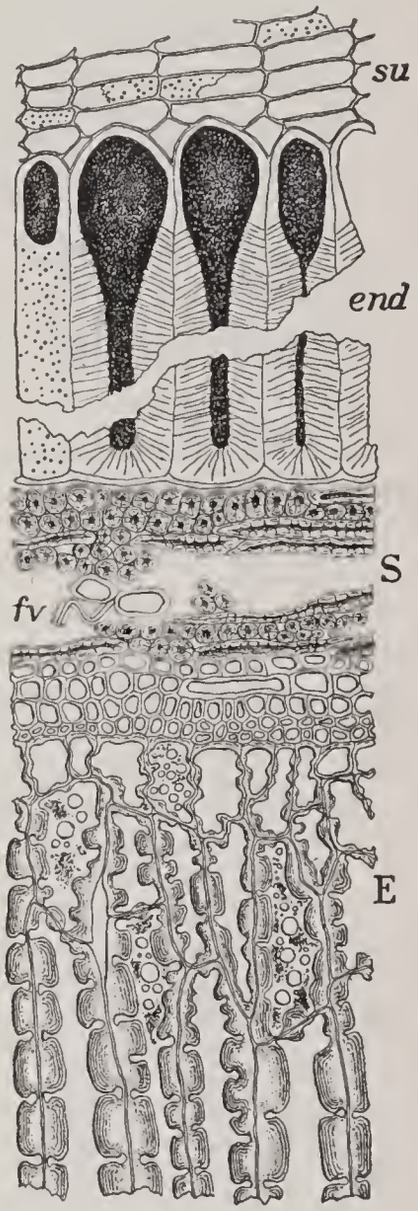


FIG. 159.—Ivory Nut in cross section. Pericarp: *su* cork, *end* palisade cells. *S* spermoderm: *fv* raphe bundle. *E* endosperm. ×160. (A.L.W.)

MICROSCOPIC STRUCTURE (Fig. 159). **Pericarp.**—The outer coat consists of *cork cells* (*su*) in several rows; the inner coat is a single-cell layer of curious *palisade cells* (*end*) about 400 μ high, with richly porous walls and funnel-shaped lumen, each, as shown by Molisch,[1] containing a siliceous body in a black mass.

The entire dissimilarity of both coats to any in the cocoanut or palm nut is noteworthy. Further morphological studies seem desirable.

Spermoderm (*S*).—The *outer layers* are of rounded cells in loose contact with thick walls and dark brown contents, the *inner layers* of polygonal cells in close contact with thinner walls and light brown contents. Between the two run the *raphe bundle* (*fv*) and its branches, through which the separation of the kernel takes place.

Endosperm (*E*).—As seen in cross section the cells increase in radial elongation and wall thickness from without inward. The double walls in the interior of the nut reach the remarkable thickness of 50 μ. Pores, enlarged at the middle lamellæ, are conspicuous. Oil drops and formless matter constitute the cell contents.

CHIEF STRUCTURAL CHARACTERS.—Nut gray-brown, irregular, with excrescence at base; shell thin, brittle; spermoderm separating through the raphe; endosperm hard, white.

[1] Centr. Org. Waarenk. Tech. 1891, p. 103.

Outer shell of cork-like cells, inner shell of funnel-shaped cells up to 400 μ, each with a siliceous body. Spermoderm of stone cells. Endosperm with enormously thick (50 μ), porous walls; contents oil and disorganized matter.

CHEMICAL COMPOSITION.—Chief interest centers in the cell-wall material that forms by far the greater part of the seed. Although hard and ivory-like in structure and lacking any considerable amount of carbohydrate in the cell cavity, the by-product from the button industry has long been known to have decided feeding value for farm animals. Beals [1] states that the annual importation into the United States is about 10,000 tons valued at $1,500,000.

In the course of a study of the composition and feeding value of ivory nut meal by Beals and Lindsey [2] analyses were made as shown in the following summary:

Composition of Ivory Nut Meal (Beals and Lindsey)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min	6.13	3.94	0.60	74.17	6.13	0.80
Max	12.64	5.26	1.18	77.56	7.75	2.30
Aver	11.39	4.63	0.92	75.09	6.89	1.80

An early American analysis [3] showed: water 18.78, protein 3.37, fat 0.70, nitrogen-free extract 68.57, fiber 7.50, and ash 1.08. German analyses fall within the range of those given herewith.

Carbohydrates.—Beals and Lindsey [2] found that 92.5 per cent of the nitrogen-free extract is *mannan*, yielding on hydrolysis mannose, and that 2.5 per cent of *pentosans* is present. No evidence was found of lignin, galactan, starch, and dextran. The great bulk of the seed is accordingly cell-wall carbohydrate convertible into hexose sugar or its equivalent. Fed to sheep and cows 84 per cent of the dry matter and 92 per cent of the nitrogen-free extract were digested and utilized.

Bourquelot and Herissey,[4] Hudson [5] and Horton [6] have developed methods of preparation of mannose from ground ivory nut.

[1] J. Ind. Eng. Chem. 1915, **7**, 161.
[2] J. Agr. Res. 1916, **7**, 301.
[3] Connecticut Agr. Exp. Sta. Rep. 1880, p. 86.
[4] Compt. rend. 1901, **133**, 302.
[5] J. Am. Chem. Soc 1917, **39**, 470.
[6] J. Ind. Eng Chem. 1921, **13**, 1040.

Bertarelli [1] states that the meal spread out in a thin layer, moistened with phloroglucinol and hydrochloric acid, and warmed, becomes orange, changing later to amaranth red. Sawdust treated in like manner at once takes on an amaranth red color.

Enzymes.—Paton, Nanji, and Ling [2] by the action of malt diastase on ivory nut shavings suspended in water obtained a considerable amount of reducing sugar. Previous boiling of the suspended shavings inhibited the action of the enzyme. The shavings themselves contain an enzyme that acts on the mannan, forming mannose.

[1] Z. Unters. Nahr.-Genussm. 1907, **13,** 484.
[2] Biochem. J. 1924, **18,** 451.

NUTS OF THE WALNUT FAMILY

(*Juglandaceæ*)

TREES of two genera, *Juglans* (walnuts) and *Carya* (hickories), are valuable for their nuts as well as their timber. Edible oil is made on a commercial scale from English walnuts and to some extent from other nuts of the family.

COMPARATIVE MACROSCOPIC STRUCTURE.—The common *nuts* of the two genera may be classified as follows:

Husk indehiscent (*Juglans*).
- Nut nearly isodiametric, four-celled at base:
  - Nut smooth ..... English walnut (*J. regia* L.)
  - Nut rough ..... Black walnut (*J. nigra* L.)
- Nut elongated, two-celled at base:
  - Nut smooth ..... Japanese walnut (*J. Sieboldiana* Maxim.)
  - Nut rough ..... Butternut (*J. cinerea* L.)

Husk separates as four segments (*Carya*).
- Nut elongated, cylindrical; shell and husk thin ..... Pecan (*Carya Pecan* E. et G.)
- Nut flattened, angled, as broad as long; shell and husk thick ..... Hickory nut (*Carya ovata* Koch)

All the species have a hard endocarp, a thin spermoderm and endosperm, and fleshy, much wrinkled, two-lobed cotyledons. The seed is orthotropous.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—The shell or endocarp consists of a dense stone cell tissue with a thin lining of brown parenchyma. Of the **Spermoderm** tissues the outer epiderm is of special interest because of the characteristic curved guard cells of the raised stomata. Young [1] (quoting Godfrin [2]) relies on the degree of curving of the guard cells in diagnosis but the distinctions are of questionable validity.

The following table gives characters of spermoderm tissues dependable in identifying some of the species.

Perisperm.—Reduced to a structureless membrane.

Endosperm.—Only a single layer (two to three cells thick in vicinity of vascular bundles) is usually present.

[1] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160**, 15.

[2] Soc. Sci. Nancy. 1880, p. 138.

	Outer epiderm in surface view	Outer epiderm in cross section	Subepiderm
English walnut	Isodiametric, straight-walled	Higher than broad	Not differentiated
Black walnut	Isodiametric, straight-walled	Isodiametric	
Japanese walnut	Isodiametric, straight-walled	Isodiametric	
Butternut	Isodiametric, straight-walled	Isodiametric	
Pecan	Elongated, straight-walled	Broader than high	Like epiderm
Hickory nut	Elongated, wavy-walled, beaded	Broader than high	

Cotyledons.—Small aleurone grains and fat are the visible cell contents, the aleurone grains seldom exceeding 10 μ.

COMPARATIVE CHEMICAL COMPOSITION.—Members of the group differ somewhat in the content of protein (15 to 30 per cent) and oil (60 to 70 per cent). The analyses available indicate that black walnut, Japanese walnut, and butternut are characterized by relatively high protein and low oil; English walnut, pecan, and hickory nut by relatively low protein and high oil.

Proteins.—English walnut, black walnut, and butternut appear to contain the same globulin, juglansin. Too little work has been done on the proteins of species of *Carya* (pecan and hickory nut) to warrant conclusions.

Oil.—High iodine number characterizes the fatty oil of the English walnut (138 to 152), black walnut (upward of 170), Japanese walnut (151), and butternut (129). Lower iodine number is characteristic of the oil of pecan and hickory nut (both between 100 to 107). These differences are due to higher content of linolein in the *Juglans* group which in English walnut reaches over 70 per cent, whereas in the pecan nut of the *Carya* group it is less than 25 per cent.

ENGLISH WALNUT

Juglans regia L.

Fr. Noyer commun. Sp. Nogal. It. Noce. Ger. Walnuss.

It is probable that the English or Persian walnut is a native of a belt extending from southeastern Europe eastward to the Pacific Ocean. At present it is cultivated in England and throughout southern Europe, also on a large scale in California. Wood of the tree is much used in cabinet work throughout Europe.

MACROSCOPIC STRUCTURE (Fig. 160).—Commercial *nuts* are light brown but this color is due to bleaching. Not only is the *shell* thinner than that of the other walnuts but it may be readily split in half

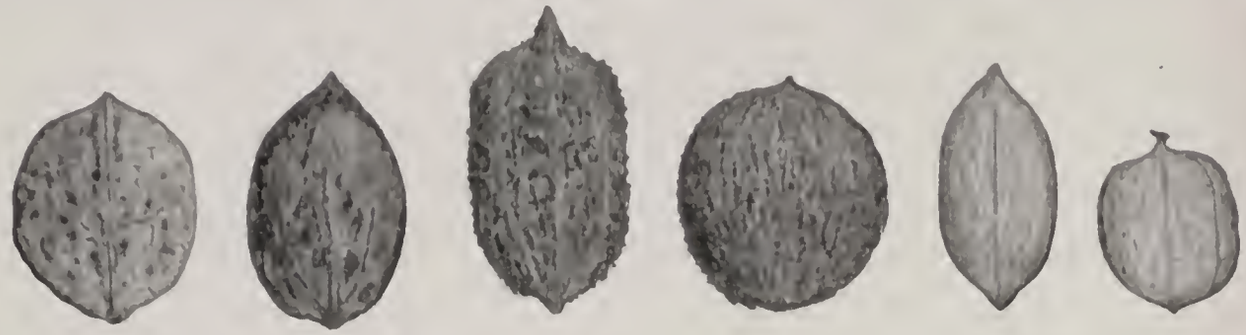


Fig. 160. English walnut. Fig. 161. Japanese walnut. Fig. 162. Butternut. Fig. 163. Black walnut. Fig. 164. Pecan. Fig. 165. Hickory nut.

All ×½. (A.L.W.)

with a knife through the suture. Thin partitions separate the two cotyledons and their lobes, making the seed four-celled at the base.

MICROSCOPIC STRUCTURE. Pericarp.—The *endocarp* or shell consists chiefly of a mass of colorless stone cells which in the outer part are

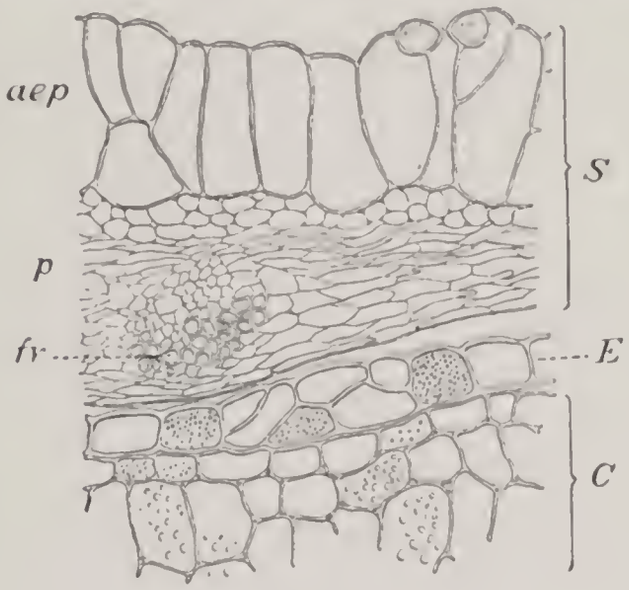


Fig. 166.

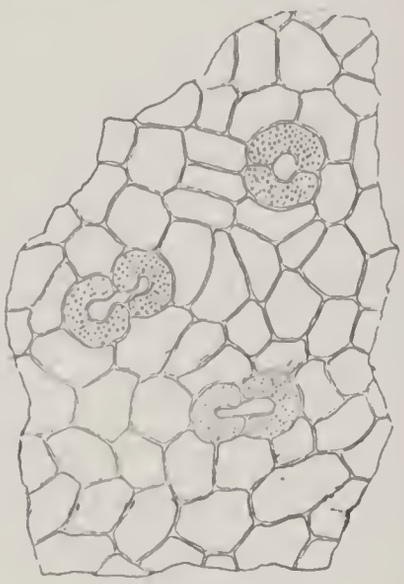


Fig. 167.

Fig. 166.—English Walnut. Seed in cross section. *S* spermoderm: *aep* outer epiderm with stoma, *p* collapsed parenchyma with *fv* vascular bundle. *E* endosperm. *C* cotyledon. ×160. (K.B.W.)

Fig. 167.—English Walnut. Outer epiderm of spermoderm in surface view showing three forms of stomata. ×160. (K.B.W.)

small, isodiametric with thick walls and narrow lumen and in the inner part are larger with thinner walls and broader lumen. No contents are visible. Brown *spongy parenchyma* forms the inner shell.

Spermoderm (Fig. 166, *S*; Fig. 167).—Only three layers are present, the subepiderm not being differentiated: (1) *outer epiderm* (*aep*) in

surface view of nearly isodiametric cells with straight walls, in cross section radially elongated, and raised stomata with more or less curved guard cells, (2) *middle spermoderm* of more or less compressed, characterless parenchyma (*p*), also vascular bundles (*fv*), and (3) inner epiderm of indistinct tangentially elongated cells.

Usually the *outer epiderm* cells are about twice as high as broad. Sometimes they are divided by a tangential wall into two cells. Differences in the curving of the guard cells of the stomata are shown in Fig. 167.

Perisperm.—Reduced to a membrane.

Endosperm (Fig. 166, *E*).—Except near the vascular bundle only one cell layer is usually present. The contents are small aleurone grains and fat.

Cotyledons (Fig. 166, *C*).—The *aleurone grains* are small, seldom reaching 10 μ.

Chief Structural Characters.—Nut smooth, nearly isodiametric, thin-shelled, splitting at the suture. Spermoderm and endosperm thin. Cotyledons fleshy.

Endocarp of stone cells, smallest but thickest-walled in outer part. Spermoderm with cells of outer epiderm in surface view nearly isodiametric, in cross section radially elongated; guard cells of stomata more or less curved. Endosperm mostly of one cell layer. Cotyledons with small aleurone grains.

CHEMICAL COMPOSITION.—Colby [1] includes the walnut in his extensive analyses of California nuts.

Composition of Kernels of California Walnuts (Colby)

	Kernel*	Water	Protein	Fat	N-f.ext.†	Fiber	Ash
	%	%	%	%	%	%	%
Soft-shell varieties:							
Min.	38.4	2.5	14.3	60.0	14.5	1.4	1.2
Max.	45.1	2.5	20.4	67.0	19.1	3.2	1.6
Aver.	**41.9**	**2.5**	**16.6**	**63.4**	**16.1**	**2.6**	**1.4**
Bijou	26.9	2.5	18.4	64.4	13.1	1.4	1.7

* Per cent in nut. † Includes fiber.

Four European analyses compiled by König [2] showed 15.82 to 17.96 per cent of protein and 54.59 to 67.15 per cent of fat, on the dry basis.

[1] California Agr. Exp. Sta. 1896, Bul. **113.**

[2] Chem. mensch. Nahr.-Genussm. 1903, **1**, 611.

Pfister [1] quotes Prof. Mariani of Locarno to the effect that walnut oil is produced in considerable amount only in the Muggio valley, the press cake of that region containing 41.8 per cent of protein and 12.5 per cent of fat.

English Walnut Shells.—An analysis by Winton, Ogden, and Mitchell [2] yielded:

	%
Water	7.69
Protein (N×6.25)	1.69
Ether extract, volatile	0.12
Ether extract, fixed	0.55
Alcohol extract	1.84
Reducing matters *	19.30
Starch by diastase	1.01
Quercitannic acid	2.08†
Fiber	56.58
Ash, total	1.40
Ash, water-soluble	0.77
Ash, acid-insoluble	0.00

* By direct inversion. † Equivalent to 0.53 per cent of O absorbed by aqueous extract.

Proteins.—The globulin of the English walnut was found by Osborne and Campbell [3] to have practically the same elementary composition as that of the hazelnut, hence the name *corylin* was applied to both. Later because 0.42 per cent more ammonia was liberated by Hausmann's method the globulin of the walnut group, including the English walnut, the black walnut, and the butternut, was judged to be distinct from the corylin of the hazelnut and was designed *juglansin*.

Ultimate Composition of Juglansin.—The following is Osborne and Campbell's analysis:

	%
Carbon	50.64
Hydrogen	6.79
Nitrogen	19.07
Sulphur	0.89
Oxygen	22.61
	100.00

The *Specific Rotation of Juglansin*, as determined by Osborne and Harris [4] for the different nuts of the group, is: English walnut −45.21°,

[1] Landw. Vers.-Stat. 1894, **43**, 441.
[2] Connecticut Agr. Exp. Sta. Rep. 1898, p. 210.
[3] Connecticut Agr. Exp. Sta. Rep. 1895, p. 288.
[4] J. Am. Chem. Soc. 1903, **25**, 842.

black walnut −44.43°, butternut −45.40°—all within limits of analytical error and noticeably different from the specific rotation of corylin, which is −43.09°.

Nitrogen Distribution in Juglansin.—Results by Osborne and Harris [1] on the percentage of nitrogen in the different forms follow: basic (diamino) nitrogen 5.41, non-basic (monoamino) nitrogen 11.51, nitrogen in magnesium oxide precipitate (humin) 0.15, and amide nitrogen 1.78; total nitrogen 18.84 per cent.

Amino Acids of English Walnut Globulin.—Jones, Gersdorff, and Moeller [2] obtained the following: cystine 2.18 and tryptophane 2.84 per cent.

Oil.—Walnut oil, known in Central Europe as nut oil, is excellent for salads, but its chief use is in artists' colors and fine varnishes. It has drying properties similar to those of hemp and poppy oils.

Physical and Chemical Values.—Following are the limits of analyses found in the literature:

	Sp. gr. 15.5° C.	Refractive index 25° C.	Solidifying point	Maumené No.	Saponification No.	Iodine No.
			° C.			
Min.....	0.922	1.4724	−28	96	186	138
Max.....	0.927	1.4752	−12	101	198	152

Jamieson and McKinney [3] secured the following results in the examination of California walnut oil: specific gravity at 25° C. 0.9235, refractive index at 25° C. 1.4751, saponification number 194.5, iodine number (Hanus) 158.5 and (Wijs) 161.7, Reichert-Meissl number 0.11, Polenske number 0.19, acetyl number 6.09, acid number 5.11, saturated acids 5.34 per cent, unsaturated acids 89.74 per cent, iodine number of unsaturated acids 166.7, hexabromide 8.88 per cent, and unsaponifiable matter 0.51 per cent.

Composition.—From the foregoing data Jamieson and McKinney calculate the percentage composition of walnut oil as shown below.

Matthes and Rossié [4] obtained similar results but did not separate the solid acids.

Carbohydrates.—Data on the carbohydrates of the walnut being

[1] J. Am. Chem. Soc. 1903, **25,** 848.
[2] J. Biol. Chem. 1924, **62,** 183.
[3] Oil Fat Ind. 1929, **6,** 21.
[4] Arch. Pharm. 1918, **256,** 302.

Glycerides of:	%
Arachidic acid	trace
Stearic acid	0.9
Palmitic acid	4.6
Myristic acid	trace
Oleic acid	17.6
Linolic acid	72.8
Linolenic acid	3.2
Unsaponifiable matter	0.5
	99.6

lacking, the reader is referred to results obtained in the analysis of the pecan nut.

Phosphorus-Organic Compounds.—Bielecki and Sztencel [1] have studied the *lecithin* and *phytin* of the English walnut. From the 0.2 per cent hydrochloric acid extract they precipitated the calcium and magnesium salts of inositolpentaphosphoric acid. They also prepared copper and lead salts.

Mineral Constituents.—Analyses by Colby [2] of the husk, shell, and kernel of California walnuts, made primarily to show the amounts of plant food taken from the soil, follow:

Analyses of California English Walnut Ash (Colby)

	Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3 †	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
Husk	1.73	77.80	0.27	7.79	1.80	0.62	0.12	2.46	2.66	1.28	6.57
Shell	0.52	28.28	0.82	44.88	5.29	1.78	0.96	13.14	3.23	1.17	0.41
Kernel	1.13	12.69	0.96	5.57	16.60	3.23	0.35	57.83	1.31	0.75	0.70

* In part ashed. † Includes Al_2O_3.

Minor Mineral Constituents. *Manganese.*—Kernel 4.03, shell 1.85 mg. per kilo, dry basis (Quartaroli).[3]

Copper.—Kernel 11.2 mg. per kilo (Guerithault).[4] Kernel 10.65, shell 2.85 mg. per kilo, dry basis (Quartaroli).[3]

Zinc.—Kernel 20 mg. per kilo, fresh basis (Bertrand and Benzon).[5]

JAPANESE WALNUT

Juglans Sieboldiana Maxim.

American nurserymen now catalog this tree. The nuts resemble the butternut in texture and flavor.

[1] Roczniki Chem. 1924, **4**, 63.
[2] Loc. cit.
[3] Ann. chim. appl. 1928, **18**, 47.
[4] Compt. rend. 1920, **171**, 196.
[5] Bul. soc. hyg. aliment. 1928, **16**, 457.

MACROSCOPIC STRUCTURE (Fig. 161).—The *nut* is longer and usually smaller and thicker-shelled than the English walnut and is two-celled at the base.

MICROSCOPIC STRUCTURE. Pericarp.—The stone cells of the *endocarp* are somewhat larger than those of the other walnuts but like those of the butternut have dark contents.

Seed.—See Black Walnut.

CHEMICAL COMPOSITION.—In the kernel of the Japanese walnut Matsumoto and Uyeda [1] found 4.99 per cent of water and 59.58 per cent of oil with the following values: specific gravity at 15° C. 0.9332, refractive index at 25° C. (recalculated) 1.4782, solidifying point below −16° C., saponification number 191.1, iodine number (Hübl) 150.8, Reichert-Meissl number 0.62, and acid number 0.68.

BUTTERNUT

Juglans cinerea L.

Fr. Noix de beurre. Ger. Butternuss.

Trees of this species, also known as the white walnut, grow native in the United States and may also be obtained from nurserymen. The flavor is milder than that of the black walnut.

MACROSCOPIC STRUCTURE (Fig. 162).—The *nut* is elongated, exceedingly rough owing to long rows of irregular teeth, and two-celled at the base. Because of the thick, hard shell it is difficult to crack.

MICROSCOPIC STRUCTURE. Pericarp.—Stone cells with very thick walls and narrow lumen make up the bulk of the *endocarp* or shell. The visible contents are yellow-brown.

Seed.—See Black Walnut.

CHEMICAL COMPOSITION.—Woods and Merrill [2] found in a single sample: shell 86.4 and kernel 13.6 per cent. In the kernel of the sample they found:

Water	Protein	Fat	N-f. ext.	Ash
% 4.5	% 27.9	% 61.2	% 3.4	% 3.0

Oil.—Examination of ether-extracted butternut oil by Merrill [3]

[1] J. Chem. Ind. (Japan) 1922, **25**, 1438.
[2] Maine Agr. Exp. Sta. 1899, Bul. **54**.
[3] Ibid. 1900, Bul. **65**.

showed: specific gravity at 15.5° C. 0.9309, refractive index at 25° C. 1.4768, and iodine number 129.1.

BLACK WALNUT

Juglans nigra L.

Fr. Noyer noir. Sp. Nuez de San Juan. Ger. Schwarze Walnuss.

This American nut is the product of a tree, the wood of which, known as black or American walnut, is valuable for cabinet work. Although not so important commercially as the English walnut, the nut has a pleasing resinous flavor and is delicious in confectionery.

MACROSCOPIC STRUCTURE (Fig. 163).—After removal of the dark outer pericarp, some of which remains between the ridges of the endocarp, the *nut* is nearly spherical. It is four-celled at the base. The endocarp is thick, with rough, longitudinal ridges.

MICROSCOPIC STRUCTURE. Pericarp.—All the stone cells of the *endocarp* have thick walls and are in close contact which explains why the shell is harder than that of the English walnut. They have no visible contents.

Spermoderm.—Cross sections show no marked elongation of the cells of the *outer epiderm*, thus distinguishing the nut from the English walnut.

Perisperm, Endosperm, and Embryo.—See English Walnut.

CHIEF STRUCTURAL CHARACTERS.—Nut rough, nearly spherical, thick-shelled. Endocarp stone cells thick-walled, in close contact. Spermoderm with cells of outer epiderm nearly isodiametric in surface view and cross section.

CHEMICAL COMPOSITION.—An analysis of the kernel of the nut by Colby [1] follows:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
2.5	30.3	57.8	5.8	1.6	2.0

M'Clenahan [2] analyzed the kernel at different stages of development and found that the fat increases out of all proportion to the increase or decrease of other constituents and is evidently not formed from starch, sugar, or tannin.

[1] California Agr. Exp. Sta. 1896, Bul. **113.**

[2] J. Am. Chem. Soc. 1909, **31,** 1093.

Proteins. *Nitrogen Distribution.*—Van Slyke's method, applied directly to the ground kernels, gave in the hands of Nollau[1] the following distribution in percentages of the total nitrogen:

	%
Humin N	4.53
Cystine N	1.27
Arginine N	23.77
Lysine N	3.49
Histidine N	5.98
Mono-amino N	45.01
Non-amino N	3.12
Amide N	10.71
Total N	97.88

Oil.—The *Physical and Chemical Values* of hot pressed oil, as given by Stone,[2] are: specific gravity at 15.5° C. 0.917, solidifying point below −20° C., saponification number 269 to 290, iodine number upward of 170, and volatile acids none.

PECAN

Carya Pecan E. et G. = *Juglans Pecan* Marsh = *Hicoria Pecan* Brit.
Fr. Noix pecane. It. Pecana. Ger. Pekannuss.

In the United States this nut is of greater commercial importance than any other native nut. It is produced in large quantities in Texas and the lower Mississippi Valley. The pecan and the English walnut are the only nuts of the family commonly present in mixed nuts sold in the United States.

MACROSCOPIC STRUCTURE (Fig. 164).—Two physical characters contribute to make this nut popular—the thin shell and the excellent flavor of the meat. The *nut* is elongated, nearly round in cross section, smooth, and four-celled at the base. The red color and gloss of commercial nuts are due to dyeing and polishing.

MICROSCOPIC STRUCTURE. Pericarp.—Small stone cells with brown contents and a loose brown parenchyma make up the *endocarp* or shell.

Spermoderm (Fig. 168, *S*; Fig. 169).—Four layers are well differentiated: (1) *outer epiderm* (*aep*) of tangentially elongated, straight-walled cells, in cross section usually broader than high, and stomata, (2)

[1] J. Biol. Chem. 1915, **21**, 611.
[2] Agr. Sci. 1894, **8**, 353.

subepiderm, similar to the outer epiderm, (3) *parenchyma* (*p*) with vascular bundles (*fv*), and (4) characterless *inner epiderm*.

Young [1] notes the tangential elongation of the outer epiderm cells of this and the hickory nut.

Commonly the opening of the *stomata* is broader than the guard cells, and the latter are brown, not white as in hickory nut. Often one of the guard cells is abortive.

Perisperm and **Cotyledons** as in English walnut but **Endosperm** is thinner.

Chief Structural Characters.—Nut elongated, circular in cross section, thin-shelled.

Endocarp stone cells small with brown contents. Outer epiderm of spermoderm with tangentially elongated, straight-walled cells,

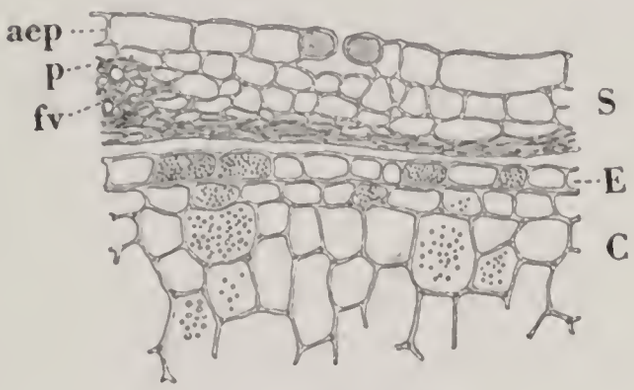


Fig. 168.

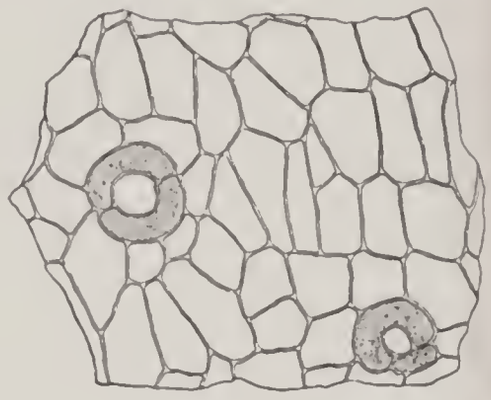


Fig. 169.

Fig. 168.—Pecan. Seed in cross section. *S* spermoderm: *aep* outer epiderm, *p* parenchyma with *fv* vascular bundle. *E* endosperm. *C* cotyledon. ×160. (K.B.W.)

Fig. 169.—Pecan. Outer epiderm of spermoderm in surface view showing two stomata, the lower with abortive guard cell. ×160. (K.B.W.)

broader than high, and brown stomata, often with one guard cell abortive.

CHEMICAL COMPOSITION.—Much attention has been given to the composition of the pecan nut in the region of production, notably by Deiler and Fraps [2] of the Texas Experiment Station and by Friedemann [3] and Dowell and Menaul [4] of the Oklahoma Experiment Station. Analyses by Woods and Merrill [5] and by Boone [6] have also been published.

[1] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160**, 15.

[2] Am. Chem. J. **43**, 90.

[3] J. Am. Chem. Soc. 1920, **42**, 2286; Proc. Okla. Acad. Sci., Univ. Okla. Bul. 1922, N.S. 47, p. 71.

[4] J. Biol. Chem. 1921, **46**, 437.

[5] Maine Agr. Exp. Sta. 1899, Bul. **54**.

[6] Ind. Eng. Chem. 1924, **16**, 54.

Composition of Pecan Nut Kernels

	Kernel*	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Deiler and Fraps..	47.0	.....	.....	70.4			
Woods and Merrill:							
Polished.....	46.8	3.0	11.0	71.2	13.3		1.5
Unpolished.....	53.7	2.7	9.6	70.5	15.3		1.9
Friedemann:							
Single sample...	.....	3.75	12.27	69.76	10.81	1.71	1.70
Aver. 14 samples.	.....	3.20	11.0	71.99	10.04	2.2	1.57
Boone.....	60.0	.....	.....	75.0			

* Per cent in nut.

Proteins. *Nitrogen Distribution.*—Nollau [1] applied Van Slyke's method directly to the ground nut. Dowell and Menaul,[2] however, first extracted the protein of the kernel, consisting largely of globulin, with dilute alkali and precipitated it with acetic acid.

Nitrogen Distribution in Pecan

	Nollau	Dowell and Menaul
	%	%
Humin N.....	6.21	5.58
Cystine N.....	2.87	0.80
Arginine N.....	6.91	23.39
Lysine N.....	3.25	5.62
Histidine N.....	21.91	3.96
Mono-amino N.....	42.28	52.10
Non-amino N.....	7.89	....
Amide N.....	9.43	....
Total N.....	100.75	91.45

Oil. *Physical and Chemical Values.*—Merrill [3] found in pecan oil obtained by ether extraction: specific gravity at 15.5° C. 0.9212, refractive index at 25° C. 1.4690, and iodine number 99.5.

Deiler and Fraps [4] have published the following values of the ether-extracted oil from Texas nuts: specific gravity at 15° C. 0.9184, saponification number 198, iodine number (Hübl) 106, Reichert-Meissl number

[1] J. Biol. Chem. 1915, **21**, 611.
[2] Loc. cit.
[3] Maine Agr. Exp. Sta. 1900, Bul. **54**.
[4] Loc. cit.

2.2, Hehner number 93.4, acetyl number 1.16, saturated acids none, lecithin 0.5 per cent, and cholesterol 0.28 per cent.

Boone,[1] also working on the ether extract, records the following values of the oil from the Schley variety grown in Georgia: specific gravity 20°/20° 0.9118; refractive index at 25° C. 1.4682; saponification number 191.5; iodine number (Hübl) 97.1; acid number 0.80; total fatty acids, neutralizing value 196.7, iodine number 100.6; saturated acids 3.8 per cent; unsaturated acids, specific gravity 20°/20° C. 0.8962, neutralizing value 197.1, iodine number 105.4.

Composition.—Calculations of the percentages of the glycerides in pecan oil by the above-named authors, also by Jamieson and Gertler,[2] follow:

	Deiler and Fraps	Boone	Jamieson and Gertler
	%	%	%
Glycerides of:			
Arachidic acid	.....	.....	0.1
Stearic acid	.....	4	1.9
Palmitic acid	.....		3.3
Myristic acid	.....	.....	trace
Oleic acid	76	80	77.8
Linolic acid	24	16	15.8
Unsaponifiable matter	.....	.....	0.35
	100	100	99.25

Carbohydrates. — Friedemann,[3] in the dry matter of the single sample, whose proximate analysis appears in the table above, determined the individual carbohydrates as shown below:

	%
Sucrose	1.18
Invert sugars	2.88
Araban	1.95
Methylpentosans	0.22
Fiber	1.76
Amyloid	0.59
Tannins	0.33
Hemicellulose (dextran), etc	4.09
	13.00

[1] Loc. cit.
[2] Oil and Fat Ind. 1929, 6, No. 10, 23.
[3] Loc. cit.

The total percentage of carbohydrates (13.00 per cent) on the dry basis corresponds to the sum of the percentages of nitrogen-free extract and fiber (10.81 + 1.71 = 12.52) on the air-dry basis.

HICKORY NUT

Carya ovata Koch = *C. alba* Nutt. = *Hicoria ovata* Brit.

The nut of the shag-bark hickory is the best hickory nut of the northern United States. Other species yield nuts with smaller meats or of inferior flavor.

MACROSCOPIC STRUCTURE (Fig. 165).—The *nut* is flattened, about as broad as long, smooth, and has several ridges. Although the shell is thick it is easily cracked.

MICROSCOPIC STRUCTURE. Pericarp.—The *endocarp* stone cells and inner parenchyma are nearly colorless whereas in the pecan they are deep brown.

Spermoderm.—Young [1] notes that the cells of the *outer epiderm*, in addition to being tangentially elongated, are beaded. Another striking character is the tendency of the walls to be wavy, which does not occur in the other members of the family studied. In cross section, as in the pecan, they are broader than high. The stomata are white with opening usually less than diameter of the guard cell, whereas in pecan they are brown with opening broader than guard cell.

Chief Structural Characters.—Nut short, flattened, smooth, ridged. Shell thick.

Endocarp stone cells colorless. Cells of the outer epiderm of the spermoderm tangentially elongated, wavy-walled, beaded, broader than high.

CHEMICAL COMPOSITION.—Analyses of the native hickory nut have been made by Woods and Merrill,[2] Peterson and Bailey,[3]

Composition of Hickory Nut Kernels

	Kernel in nut	Water	Protein	Fat	N-f.ext.	Fiber	Fat
	%	%	%	%	%	%	%
Woods and Merrill	37.8	3.7	15.4	67.4	11.4		2.1
Iowa Station	30.0	3.97	20.5	64.6	6.4	2.3	2.2
Peterson and Bailey	37.2	3.45	13.2	70.2	9.42	2.0	1.73

[1] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160**, 15.
[2] Maine Agr. Exp. Sta. 1899, Bul. **54**.
[3] J. Ind. Eng. Chem. 1913, **5**, 739.

and at the Iowa Agricultural Experiment Station.[1] The species that yielded the nuts analyzed by Peterson and Bailey was known to be *C. ovata*, the shag-bark hickory, and presumably the same species yielded the other samples as the nuts of other species are seldom collected.

Proteins. *Nitrogen Distribution in Shag-bark Hickory.*—Nollau,[2] applying Van Slyke's method directly to the ground kernels, found:

	%
Humin N	6.59
Cystine N	1.58
Arginine N	24.24
Lysine N	3.37
Histidine N	6.66
Mono-amino N	43.25
Non-amino N	7.48
Amide N	9.47
Total N	102.64

Oil.—*Physical and Chemical Values* obtained on the expressed oil of the shag-bark hickory, *C. ovata*, and pignut or swamp hickory, *C. amara*, by Merrill [3] and Peterson and Bailey [4] follow:

Values of Hickory Nut Oil

	Sp. gr. 15.5° C.	Refr. index 25° C.	Saponification No.	Iodine No.	Reichert-Meissl No.	Hehner No.
Carya ovata:						
Merrill	0.9219	1.4678	.....	102.8		
Peterson and Bailey	0.9180	1.4681	189.6	106.8	0.47	95.7
Carya amara:						
Peterson and Bailey	.....	1.4681	190.0	105.2	0.48	95.6

Peterson and Bailey note that the oil resembles closely cottonseed oil. It is remarkable that this oil, as well as pecan nut oil, has an iodine number so much lower than that of English walnut oil.

[1] Proc. Iowa Acad. Sci. **10**, 108.
[2] J. Biol. Chem. 1915, **21**, 611.
[3] Maine Agr. Exp. Sta. 1900, Bul. **65**.
[4] Loc. cit.

NUTS OF THE BIRCH FAMILY

(*Betulaceæ*)

Shrubby species of *Corylus* produce edible nuts variously known as hazelnuts, filberts, and cob nuts.

The black birch secretes in its bark an essential oil, containing the same principle (methyl salicylate) as the wintergreen berry, which is described in Volume III.

FILBERT

Corylus spp.

Fr. Noisette. Sp. Avellana. It. Nocciuola. Ger. Haselnuss.

As grown in England, filberts are oblong and cob nuts are isodiametric, all being produced by cultivated species of *Corylus* (notably *C. Avellana* L., *C. pontica* Koch, and *C. maxima* Mill.) or their hybrids. Native American species (*C. rostrata* Ait., *C. americana* Walt, and *C. californica* Rose) are commonly known as hazelnuts, a term also applied to the whole genus.

MACROSCOPIC STRUCTURE.—Characteristic of the group are the bracts of the pistillate flowers which develop on ripening of the nut into a *husk*, in some species about the length of the nut or shorter ending as a fringe, in others extended well beyond the nut as a beak. The body of the *nut* is light brown, smooth, striate below, dull gray owing to a thin felt of hairs at the apex. As on the acorn and chestnut, there is a scar at the base of the nut.

The *shell*, about 1 mm. thick, consists of pericarp with meridional vascular bundles beneath the surface. Adhering to the bulky white *cotyledons* is a brown skin consisting of spermoderm with the raphe and its branches.

MICROSCOPIC STRUCTURE.—Early authors studied chiefly the pericarp which was a common adulterant in Europe. Winton,[1] also Young,[2] have worked on the seed.

Pericarp (Fig. 170, *F*).—Unlike that of nuts of the walnut group the shell consists of the entire pericarp with layers as follows: (1) *epicarp*

[1] Mic. Veg. Foods. New York, 2nd Ed., 1916, p. 311.

[2] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160**, 26.

(*epi*) of thin-walled, isodiametric cells with dark contents, also thick-walled, sinuous hairs up to 500 μ in length, (2) *outer stone cell layer* (st^1) of small, rounded, loosely arranged individuals and vascular bundles, (3) *middle stone cell layer* (st^2) of large, radially elongated, closely arranged individuals, (4) *inner stone cell layer* (st^3) of large, isodiametric to tangentially elongated individuals, and (5) *brown parenchyma* (*br*) more or less disorganized.

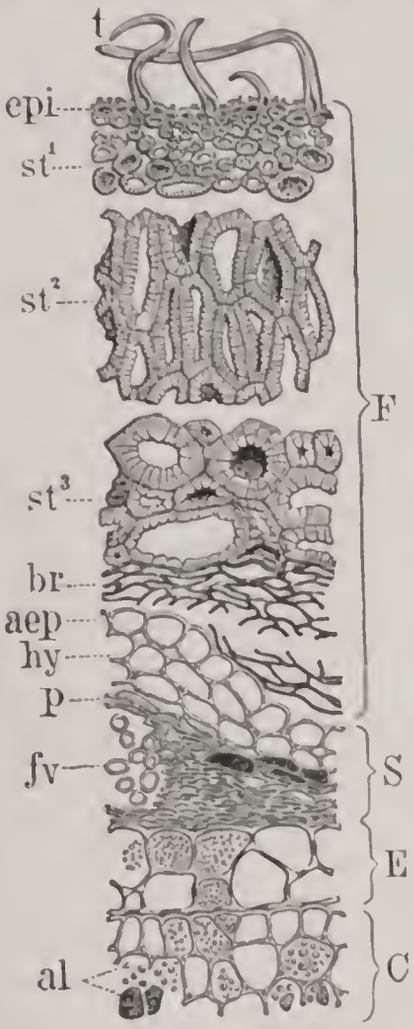


Fig. 170.—Filbert. Nut in cross section. *F* pericarp: *epi* epicarp, *t* hairs, st^1, st^2, st^3 stone cells, *br* brown parenchyma. *S* spermoderm: *aep* outer epiderm, *hy* subepiderm, *p* parenchyma, *fv* vascular bundle. *E* endosperm. *C* cotyledon: *al* aleurone grains. ×160. (K.B.W.)

The *hairs* and *epicarp* cells with very thick wrinkled cuticle and dark contents are characteristic.

All the *stone cells* also have dark contents, those in the innermost layer being of irregular, indistinct outline, as noted by Hanausek.[1]

Spermoderm (Fig. 170, *S*).—Of the three layers the *outer epiderm* (*aep*) and the *subepiderm* (*hy*) consist of polygonal cells with intercellular spaces, while the third layer is of *compressed parenchyma* (*p*) through which run the raphe bundles (*fv*).

Young first called attention to the presence of intercellular spaces which is unusual in epidermal tissues.

Endosperm (Fig. 170, *E*).—The one to three cell layers, closely united with the spermoderm, contain small *aleurone grains*.

Cotyledon (Fig. 170, *C*).—Hanausek first noted the curious elongated *aleurone grains* (*al*), one in each cell, ranging up to 30 μ in diameter. These are irregular in outline and each contains a crystal rosette, brought out by polarized light, and a number of globoids which are liberated on mounting in water. Hanausek further states that small starch grains (1 to 3 μ) are also liberated in water, but the bodies to which he refers stain brown with iodine.

Chief Structural Characters.—Nut elongated or nearly isodiametric, smooth, light brown with scar at base and felt of hairs at apex. Shell hard with bundles. Spermoderm and endosperm thin. Cotyledons fleshy.

Pericarp of epicarp cells with dark contents and thick-walled hairs, stone cells of various types with dark contents, and compressed paren-

[1] Nahr.-u. Genussm. Kassel, 1884, p. 149.

chyma. Spermoderm of thin-walled cells with intercellular spaces in outer epiderm and subepiderm. Endosperm with small aleurone grains. Cotyledons with large aleurone grains (30 μ) containing crystal rosette and globoids.

CHEMICAL COMPOSITION.—The average of the proximate analyses of the kernels (meats) given by König,[1] and a single analysis, by Woods and Merrill,[2] of a sample containing 52.1 per cent of shells, follow:

Composition of Filbert Kernels

	Water	Protein	Fat	N-f. ext.*	Ash
	%	%	%	%	%
König	7.1	17.4	62.6	10.4	2.5
W. and M.	3.7	15.6	65.3	13.0	2.4

* Includes fiber.

Proteins.—The globulin of the hazelnut (*C. tubulosa*) was first isolated by Dumas and Cahours.[3] Osborne and Campbell [4] named it *corylin* and at first considered it to be identical with the globulin of the English walnut but later found that on decomposition it yielded more ammonia.

Ultimate Composition.—Corylin, according to Osborne and Campbell,[4] contains as follows:

	%
Carbon	50.72
Hydrogen	6.86
Nitrogen	19.17
Sulphur	0.83
Oxygen	22.42
	100.00

The *Specific Rotation* of corylin, as found by Osborne and Harris,[5] is $-43.09°$.

Amino Acids of Corylin.—In "filbert globulin" Jones, Gersdorff, and Moeller [6] report: cystine 1.50 and tryptophane 2.86 per cent.

[1] Chem. mensch. Nahr.-Genussm. 1903, **1**, 611.
[2] Maine Agr. Exp. Sta. 1899, Bul. **54**.
[3] J. prakt. Chem. 1843, **28**, 398.
[4] Connecticut Agr. Exp. Sta. Rep. 1895, p. 288.
[5] J. Am. Chem. Soc. 1903, **25**, 842.
[6] J. Biol. Chem. 1924, **62**, 183.

Nitrogen Distribution in Corylin.—Figures by Osborne and Harris[1] on the nitrogen distribution in groups are here given as follows: basic nitrogen 5.75, non-basic nitrogen 10.70, nitrogen in magnesium oxide precipitate 0.16, and ammonia nitrogen 2.20; total nitrogen 19.00 per cent.

Oil.—Hazelnut oil resembles closely almond oil although the plant belongs to a different family. It furnishes a palatable substitute for olive oil.

The *Physical and Chemical Values*, as summarized below, are based on the results of De Negri and Fabris,[2] Hanus,[3] Knorr,[4] Pritzker and Jungkunz,[5] Salvatore,[6] and Merrill.[7]

VALUES OF HAZELNUT OIL

	Sp. gr. 15.5° C.	Refractive index 25° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer
						° C.
Min.....	0.914	1.4665	35	187	82	15
Max.....	0.917	1.4680	37	198	91	20

Composition.—Hanus[3] calculated the constituent acids and phytosterol with the following results:

	%
Stearic acid.....	1
Palmitic acid.....	9
Oleic acid.....	85
Phytosterol.....	0.5
	95.5

He found no acids of lesser saturation than oleic, thus disagreeing with Schädler,[8] who states that a very small amount of arachidic acid is present. Pritzker and Jungkunz[5] also were unable to detect arachidic acid.

[1] J. Am. Chem. Soc. 1903, **25**, 323.
[2] Ann. lab. chim. Gabelle.
[3] Z. Unters. Nahr.-Genussm. 1899, **2**, 617.
[4] Seifensieder Ztg. 1912, **39**, 523.
[5] Z. Unters. Nahr.-Genussm. 1921, **42**, 232.
[6] Staz. sper. agr. ital. 1922, **55**, 34.
[7] Maine Agr. Exp. Sta. 1900, Bul. **65**.
[8] Tech. Fette u. Oele, 1883, p. 477.

Hazlenut Shells.—Kryż [1] gives a series of color reactions of the coloring matter extracted by hot water from both peanut and hazelnut shells.

Minor Mineral Constituents. *Iron.*—Peeled 41 mg. per kilo, fresh basis (Haüsermann quoted by Sherman).[2]

Copper.—Kernel 12 mg. per kilo, air-dry basis (Guerithault).[3]

Zinc.—Kernel 10, shells 2.9 mg. per kilo, air-dry basis (Bertrand and Benzon).[4]

[1] Oesterr. Chem. Ztg. 1922, **25,** 95.
[2] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185.**
[3] Compt. rend. 1920, **171,** 196.
[4] Bul. soc. hyg. aliment. 1928, **16,** 457.

NUTS OF THE BEECH FAMILY

(*Fagaceæ*)

Nuts of this family are partly starchy, such as the chestnut and acorn (which see), and partly oily, such as the beechnut described herewith.

BEECHNUT

Fagus spp.

Fr. Faîne. It. Faggiuola. Ger. Bucheichel.

On the Continent carefully tended forests of beech trees (*F. silvatica* L.) produce not only timber and firewood but also nuts for oil and feed. In North America another species, *F. americana* Sweet (*F. ferruginea* Ait.), is common, but the nuts are seldom gathered.

MACROSCOPIC STRUCTURE.—A prickly *involucre*, corresponding to the bur of the chestnut and the cup of the acorn, on splitting liberates two brown triangular nuts, each containing a single *seed* developed from one of the three ovules. The raphe runs through one of the angles, the main branches through the other two. The cotyledons are much folded.

MICROSCOPIC STRUCTURE.—Hanausek [1] and Pfister [2] early studied this nut.

None of the tissues is characteristic. Brown coloring matter impregnates most of the softer tissues. As is true of other nuts of the family the **Pericarp** has a hairy *epicarp* and a dense *stone cell zone* and the **Spermoderm** is of thin-walled elements. Most of the hairs are short and thick-walled.

The endocarp and spermoderm, which are hairy in the chestnut and acorns, are smooth in the beechnut.

Crystal fibers, with single crystals, as well as bast fibers accompany the pericarp bundles.

The **Endosperm** is of one cell layer.

[1] Real Ency. ges. Pharm. 1 Auf. **7**, 407.

[2] Landw. Vers.- Stat. 1894, **43**, 445.

The **Embryo** contains aleurone grains up to 15 μ and each cell a crystal rosette.

CHEMICAL COMPOSITION.—Analyses of the European beechnut (*F. sylvatica*) have been reported by König [1] and of the American beechnut (*F. americana*) by Woods and Merrill.[2] Judging from these analyses the American nut has a smaller percentage of kernel but a higher percentage of fat in the kernel.

Composition of Beechnuts

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
European beechnut:						
König						
Kernel (66.8%)	9.09	21.67	42.49	19.17	3.72	3.86
Shell (33.2%)	15.25	3.39	1.53	35.04	42.08	2.71
Whole nut	11.13	15.59	28.89	24.46	16.45	3.48
American beechnut:						
Woods and Merrill						
Kernel (59.2%)	4.0	21.9	57.4	13.2		3.5
Whole nut	2.3	13.0	34.0	7.8		2.1

Beechnut Cake is a distinctly European product, as the American nut is not gathered on a commerical scale. The nut is pressed either whole or after shelling, and the cake is utilized as a cattle food.

Analyses reported by Wolff [3] and by Kling [4] follow:

Composition of European Beechnut Cake

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Shelled (Wolff)	12.5	37.1	7.5	29.8	5.5	7.7
Unshelled (Wolff)	16.1	18.2	8.3	28.3	23.9	5.2
Unshelled (Kling)	16.3	18.5	4.4	28.9	19.7	11.2

Oil.—The oil is expressed on a small scale in Europe and is used for food and for lighting. It is said not to easily turn rancid.

[1] Landw. Z. Westf. Lippe 1889, **46**, 38; Chem. mensch. Nahr.-Genussm. 1903, **1**, 612.

[2] Maine Agr. Exp. Sta. 1899, Bul. **54**.

[3] Landw. Fütterungslehre. Berlin, 1885, p. 224.

[4] Landw. Bayern 1916, **6**, 11, 483.

VALUES OF BEECHNUT OIL

	Sp. gr. 15.5° C.	Maumené No.	Saponification No.	Iodine No.	Hehner No.	Fatty acids, titer
						° C.
Min.....	0.920	63	191	104	95.1	
Max.....	0.923	65	197	121	95.96	17

In the oil of American beechnut (*F. americana*), obtained by ether extraction, Merrill[1] found: specific gravity at 15.5° C. 0.9178, refractive index at 25° C. 1.4697, and iodine number 97.3.

Heiduschka and Roser[2] report figures within the above limits, also the following single determinations: refractive index at 25° C. 1.4726, Reichert-Meissl number below 0.1, Polenske number below 0.1, and acetyl number 4.19.

Composition.—According to Heiduschka and Roser[2] beechnut oil contains fatty acids (not glycerides) and unsaponifiable matter as follows:

	%
Stearic acid.....	3.45
Palmitic acid.....	4.88
Oleic acid.....	76.69
α-Linolic acid.....	9.19
α-Linolenic acid.....	0.39
Unsaponifiable matter.....	0.82
	95.42

Cholin.—Beechnut cake has been stated to be injurious to horses but not to hogs and ruminants. No evidence is available that the nut is injurious to human beings.

A toxic substance, *fagin*, was described by Herberger,[3] but later Brandl and Rakowiecki[4] found only trimethylamine. Böhm[5] isolated cholin and showed that fagin is identical with it. Trimethylamine may be split off from choline.[6]

[1] Maine Agr. Exp. Sta. 1900, Bul. **65.**
[2] J. prakt. Chem. 1922, **104,** 137.
[3] Jahrb. Berz. 1833, **12,** 273.
[4] Abs. Chem. Centrbl. 1865, p. 143.
[5] Arch. exp. Path. Pharm. **19,** 87; Abs. Chem. Centralbl. 1885, p. 251.
[6] See Pfister: Landw. Vers.-Stat. 1894, **43,** 445.

SEEDS OF THE MULBERRY FAMILY

(*Moraceæ*)

Because of the use of hemp cake as a cattle food, hemp seed is described below.

HEMP SEED

Cannabis sativa L.

Fr. Chanvre. Sp. Canamo. It. Canapa. Ger. Hanf.

Hemp ranks next to cotton and flax as a textile plant and like these yields a seed useful for oil production and feeding. The plant appears to have originated in central Asia, where it still grows wild. At a very early period it was grown in the principal Asiatic countries whence, centuries before the Christian era, it was carried to central Europe. At present it is cultivated in China, Japan, India, throughout central and southern Europe, particularly Russia, northern Africa, and parts of North and South America.

As is true of flax the plant yields the best fibers before the seed reaches maturity, but with so coarse a textile this point is not vital, and in certain countries, notably Russia, quality is sacrificed in order to secure the double crop.

The variety known as Indian hemp (var. *indica*) is extensively grown as a medicinal plant. Hashish, to the use of which many millions of Asiatics are addicted, is prepared from this herb.

MACROSCOPIC STRUCTURE.—Like its near relative the hop plant, hemp is diœcious. The fertile *flower* has a single hooded calyx folded about the one-celled ovary. At maturity the *calyx* (Fig. 171, I) is upward of 1 cm. long, including the beak, and is hairy on the outer surface. The *fruit*, commonly known as hemp seed (Fig. 171, II and III), is an oval, somewhat flattened achene, up to 5 mm. long, with a rib on each of the narrow sides. Excepting the ribs and base, which are white, the surface is brown with delicate white veins. The *pericarp* (*F*) is hard and shell-like, about 0.2 mm. thick; the greenish *spermoderm* (*S*), as well as the colorless *endosperm* (*E*), is thin; the *embryo* is bulky with *radicle* (*R*) bent so as to lie beside the *cotyledons* (*C*).

MICROSCOPIC STRUCTURE.—The earlier treatises on the histology of foods, feeds, drugs, and seeds describe hemp seed incompletely

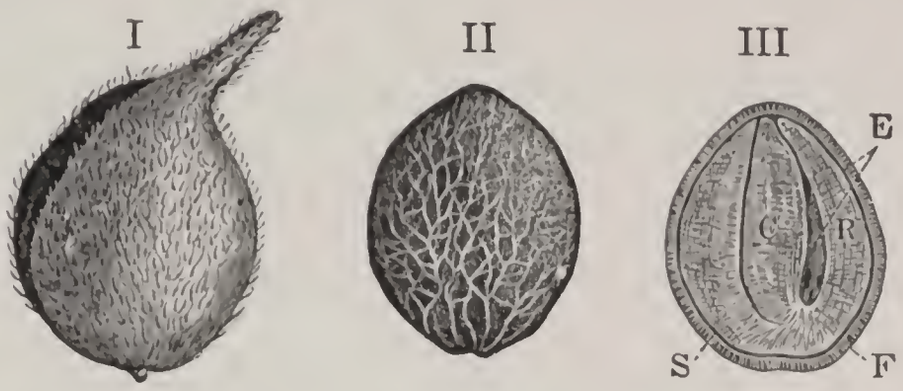


FIG. 171.—Hemp. I calyx. II outer surface of fruit. III longitudinal section of fruit. *F* pericarp; *S* spermoderm; *E* endosperm; *C* cotyledon; *R* radicle. ×4. (A.L.W.)

and inaccurately. Winton[1] carried out a study of calyx, pericarp, and seed with the view of correcting these defects.

Calyx.—Fig. 172 and the following description agree in essential details with Tschirch and Osterle's results obtained with Indian hemp. The tissues are: (1) *outer epiderm* (*aep*) of polygonal cells with unicellular cystolith hairs (*h*) and glands both stalked (*d*) and sessile, (2) *mesophyl* of small cells forming a ground tissue through which ramify bundles, and an inner layer of small (10 μ) *crystal cells* (*mes*), and (3) *inner epiderm* (*iep*) of wavy-walled cells, stomata, and thin-walled hairs.

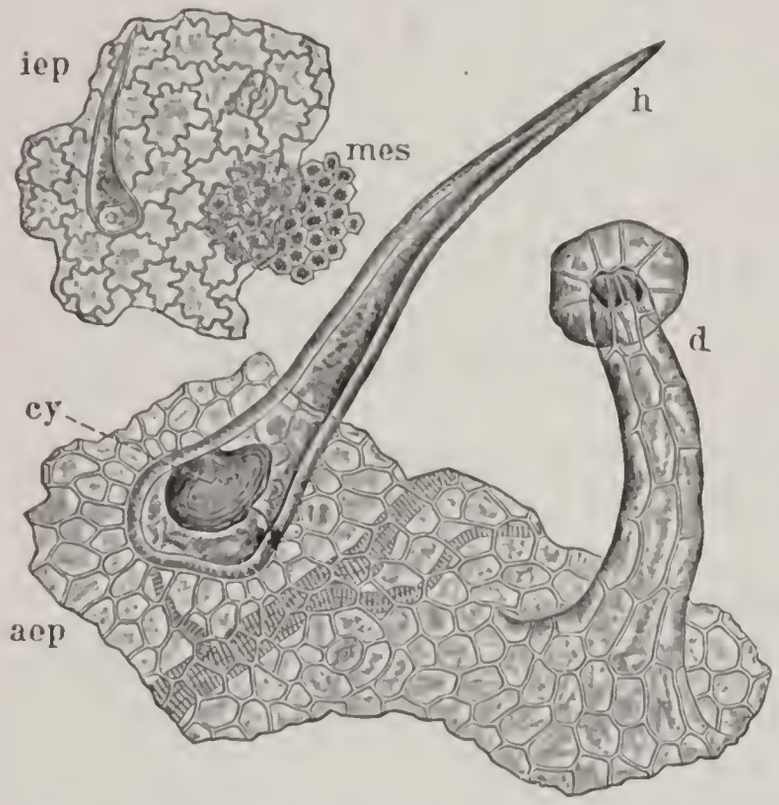


FIG. 172.—Hemp. Calyx in surface view. *aep* outer epiderm with *d* glandular hair and *h* hair containing *cy* cystolith; *mes* mesophyl with crystals; *iep* inner epiderm. ×160. (A.L.W.)

The *cystolith hairs* are highly characteristic. Each contains in its base a cystolith of calcium carbonate, 75 μ in diameter. The hairs often reach 500 μ and sometimes 1 mm. in length. Although the lumen is broad, the walls are thick, reaching 10 μ.

[1] Z. Unters. Nahr.-Genussm. 1904, 7, 385; Connecticut Agr. Exp. Sta. Rep. 1903, p. 175.

Equally striking are the *glands* with at least eight cells on the under side radiating usually from two central cells, the secretion being in the cavity between these cells and the outer cuticle. When stalked they are often 300 μ long, the stalk being multicellular.

Pericarp (Fig. 173, *F*; Figs. 174 and 175).—Five layers are present: (1) *epicarp* (*ep*) of wavy-walled sclerenchyma cells, (2) *hypoderm* (*hy*) of spongy parenchyma in one or more cell layers, with anastomosing bundles seen as veins through the epicarp, (3) *brown cells* (*br*) with zigzag walls, (4) *dwarf cells* (*w*), seldom over 12 μ in diameter, with pitted walls, and (5) *palisade cells* (*pal*, *pal*,[1] *pal*[2]) with remarkable thickened and wavy walls.

The *dwarf cells* being extraordinarily minute, it is not remarkable that they long escaped notice.

Reference to the cuts shows the structure of the *palisade cells*. Both the radial and the tangential walls are thickened and wavy, the thickening being greatest in the outer portions.

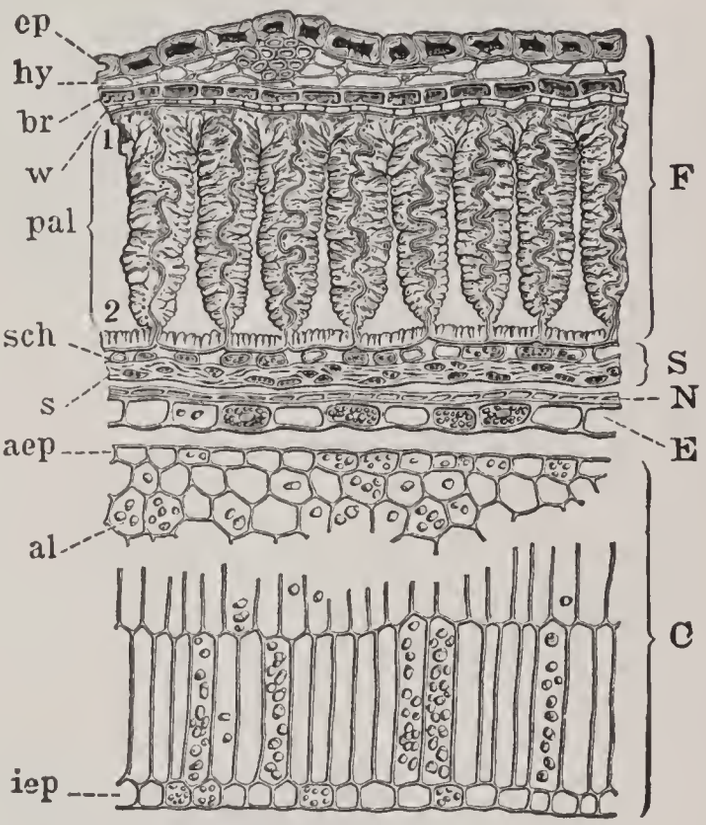


Fig. 173.—Hemp. Fruit in cross section. *F* pericarp: *ep* epicarp, *hy* hypoderm with fibrovascular bundle, *br* brown cells, *w* dwarf cells, *pal* palisade cells. *S* spermoderm: *sch* outer and *s* inner spongy parenchyma. *N* perisperm. *E* endosperm. *C* cotyledon: *aep* outer and *iep* inner epiderm, *al* aleurone grains. ×160. (A.L.W.)

Spermoderm (Fig. 173, *S*; Fig. 175).—Throughout, the tissues are of spongy parenchyma but of two different forms: (1) *outer layer* (*sch*) with cells and intercellular spaces in longitudinal rows and (2) *inner layer* (*s*) with cells and intercellular spaces irregularly arranged. Both forms contain green or brown granules insoluble in alcohol, ether, and sodium hydroxide.

Perisperm (Figs. 173 and 175, *N*).—This consists of a single layer of longitudinally elongated cells, indistinctly seen in cross section. It, together with the endosperm, suggests the corresponding layers of wheat and some other cereals.

Endosperm (Figs. 173 and 175, *E*).—Aleurone cells, mostly a single cell thick, cover the embryo. The endosperm also extends between the cotyledons and the radical where it is several cells thick.

Embryo (Fig. 173).—Each cotyledon (*C*) has *palisade cells*, two thick, on the inner side, and isodiametric cells, several thick, on the outer side. Both contain *aleurone grains* (*al*) up to 8 μ with a crystalloid and a

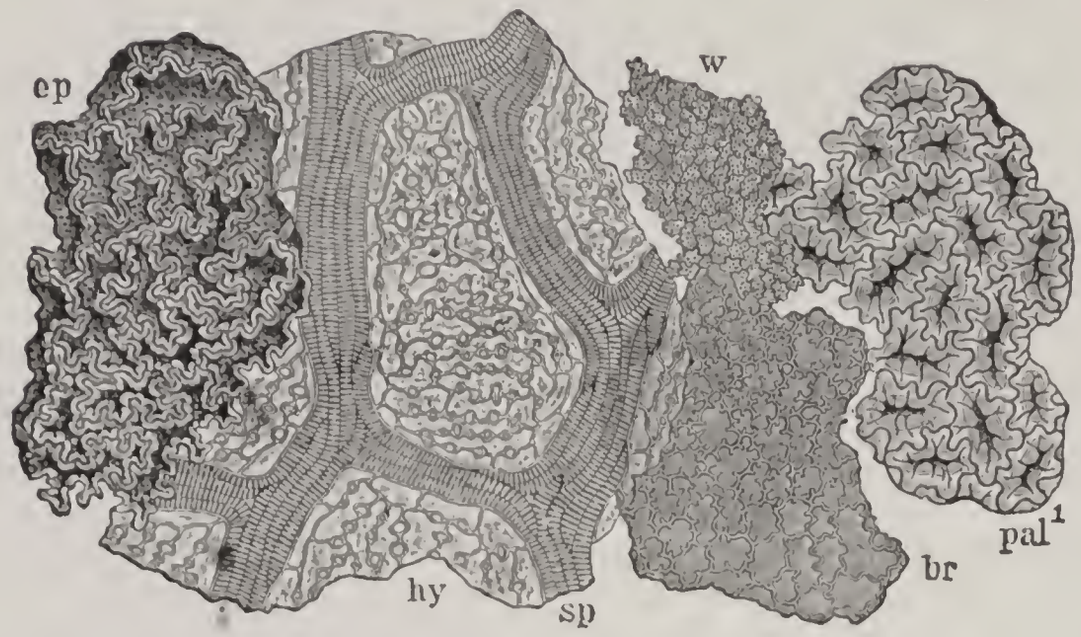


FIG. 174.—Hemp. Pericarp in surface view seen from without. *ep* epicarp; *hy* hypoderm with *sp* spiral vessels; *br* brown cells; *w* dwarf cells; *pal*¹ palisade cells. ×160. (A.L.W.)

globoid excrescence. In the epiderms (*aep*, *iep*), the aleurone grains are smaller.

CHIEF STRUCTURAL CHARACTERS.—Seed ovate, flattened, ribbed

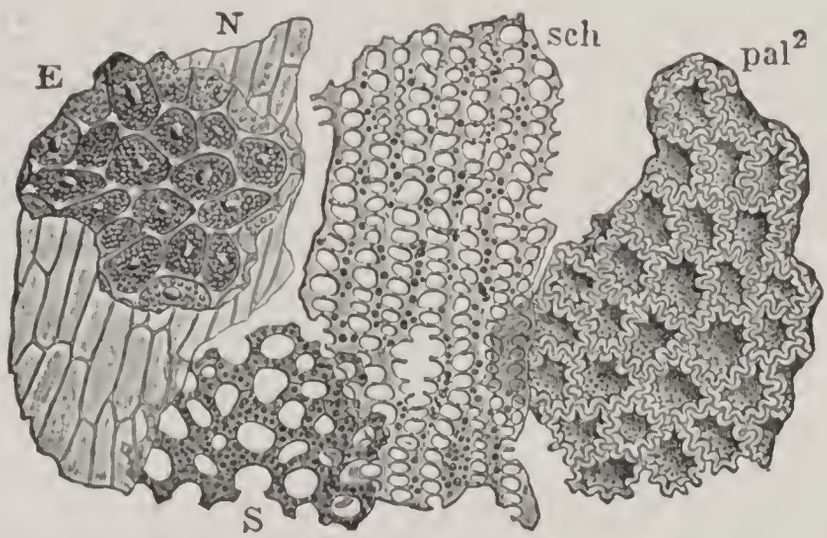


FIG. 175.—Hemp. Inner coats of seed seen from within. Spermoderm: *pal*² palisade cells, *sch* outer and *S* inner spongy parenchyma. *N* perisperm. *E* endosperm. ×160. (A.L.W.)

on narrow sides, brown, with white veins, some enclosed in hooded, hairy calyx. Pericarp hard, 0.2 mm. thick. Spermoderm and endosperm thin. Embryo bulky, bent.

Epicarp of wavy-walled cells; hypoderm with anastomosing bundles; brown cells with zigzag walls; dwarf cells minute, pitted; palisade cells with thick, convoluted walls; Spermoderm of spongy parenchyma containing green or brown granules. Endosperm of one cell layer and embryo rich in aleurone grains (8 μ) and fat.

MICROSCOPY OF HEMP SEED PRODUCTS.—Tangential and cross sections of fragments of the shells or whole pieces from cake or meal aid in identification. Treatment with a fat solvent and bleaching with Labarraque's solution or by chlorine, as recommended by Hebebrand, bring out details of structure.

CHEMICAL COMPOSITION.—Since, in the United States, hemp seed oil and hemp seed cake do not enter into commerce and hemp seed is used only as bird or poultry food, no American analysis of hemp seed or its products has come to the writers' attention.

The figures in the following summary are due to C. Böhmer.[1]

Composition of Hemp Seed (C. Böhmer)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min	6.47	15.00	29.08	13.05	12.10	3.45
Max	12.20	22.25	33.60	23.60	24.03	6.37
Aver	**8.75**	**21.51**	**30.41**	**15.89**	**18.84**	**4.60**

Frankfurt[2] has made a somewhat extensive analytical study of a single sample of hemp seed with results as follows:

Composition of Water-Free Hemp Seed (Frankfurt)

	%
Protein	18.63
Nuclein, etc.	3.36
Lecithin	0.88
Glycerides and free fatty acids	30.92
Cholesterol	0.07
Soluble carbohydrates (sucrose, etc.)	2.59
Fiber	26.33
Soluble organic acids	0.68
Bases, hemicellulose, etc.	11.03
Ash	5.51
	100.00

[1] Kraftfuttermittel. Berlin, 1903, p. 384.
[2] Landw. Vers.- Stat. 1894, **43**, 143.

Hemp Cake.—As in the case of other oil seeds the composition of the cake depends on the amount of oil expressed or extracted and the dryness. Following is a compilation of 661 analyses, made at the Experiment Station at Königsberg, Prussia, between 1877 and 1895, and reported by Lemcke in his monograph on hemp cake.[1]

Composition of Hemp Seed Cake (Lemcke)

	Water	Protein	Fat	N-f. ext.	Ash
	%	%	%	%	%
Min	8.30	26.85	7.85	.....	
Max	22.28	33.85	19.35	.....	14.60*
Aver	**10.81**	**30.76**	**10.17**	**40.59** †	**7.67**

* Usually below 10.00 per cent. † Fiber 18.02 per cent; not determined in all samples.

Proteins.—Ritthausen[2] extracted from defatted hemp seed a crystalline *globulin* which, from the ultimate analysis, he concluded was identical with the globulin obtained by Grübler[3] from squash seed. Osborne[4] corroborated this conclusion and added the globulins of castor bean and flax seed to the list of probably identical crystalline proteins. He adopted the generic name "*edestin*" for this globulin.

The *Ultimate Composition* of the globulin of the hemp seed follows:

	Ritthausen	Osborne
	%	%
Carbon	50.98	51.27
Hydrogen	6.92	6.85
Nitrogen	18.73	18.76
Sulphur	0.82	0.90
Oxygen	22.55	22.22
	100.00	100.00

Amino Acids of Edestin.—Schulze and Winterstein[5] determined the hexone bases in hemp seed edestin. Abderhalden[6] confirmed their results and added results on other amino acids separated by hydrolysis. Kossel and Patten[7] obtained somewhat higher percentages of hexone

[1] Landw. Vers.-Stat. 1901, **55**, 161.
[2] J. prakt. Chem. 1882, **25**, 130.
[3] Ibid. 1881, **23**, 97.
[4] Am. Chem. J. 1892, **14**, 662.
[5] Z. physiol. Chem. 1901, **33**, 547.
[6] Ibid. 1902, **37**, 499; 1903, **40**, 249.
[7] Ibid. 1903, **38**, 39.

bases, and Osborne and Liddle[1] much higher percentages of glutamic acid and proline.

The results in the following table are by Abderhalden except where otherwise noted:

AMINO ACIDS OF HEMP SEED EDESTIN

	%
Glycocoll	3.8
Alanine	3.6
Valine	+
Leucine	20.9
Phenylalanine	2.4
Tyrosine	2.13
Serine	0.33
Cystine	0.25
Proline	4.1 *
Oxyproline	2.0
Aspartic acid	4.5
Glutamic acid	18.74*
Tryptophane	+
Arginine	14.36†
Lysine	1.67†
Histidine	2.36†
	81.14

* Osborne and Liddle. † Kossel and Patten.

Jones, Gersdorff, and Moeller[2] found in edestin: cystine 0.97 and tryptophane 2.48 per cent.

Nitrogen Distribution in Hemp Seed.—Van Slyke's method applied directly to the ground seed by Nollau[3] gave the following results:

	%
Humin N	4.15
Cystine N	2.05
Arginine N	21.38
Lysine N	6.71
Histidine N	3.01
Mono-amino N	44.20
Non-amino N	5.28
Amide N	9.93
Total N	96.71

Oil.—Hemp oil has high drying properties; the maximum iodine number reported, however, does not quite equal the minimum for lin-

[1] Am. J. Physiol. 1910, **26**, 295.
[2] J. Biol. Chem. 1924, **62**, 183.
[3] Ibid. 1915, **21**, 611.

seed oil. It is used in paint on the Continent and in some sections as a table oil.

Physical and Chemical Values.—The following extremes are compiled from data published by Allen, De Negri and Fabris, Lewkowitsch, and others:

	Sp. gr. 15.5° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer
					° C.
Min	0.925	95	190	140	14
Max	0.933	98	195	166	17

Composition.—Hazura and Grüssner [1] give the following figures representing the composition of the liquid acids:

	%
Oleic acid	15
Linolic acid	70
Linolenic acid, Isolinolenic acid	15
	100

These figures are subject to revision by modern methods.

Phosphorus-Organic Compounds.—The percentages of *nuclein* and *lecithin* are given in Frankfurt's analysis.

Alkaloids.—*Cannabinol* ($C_{21}H_{30}O_2$), according to Fränkel,[2] is the active principle of the plant, particularly the flowering tops of the variety *indica*. The resinous extracts prepared from the plant are apparently of indefinite composition.

Whether hemp seed contains cannabinol or any other active principle seems to be uncertain. The calyx which surrounds the fruit, being morphologically a modified leaf, quite possibly has some of the chemical characters of the leaves.

Cholin is stated to be present in the plant and may also occur in the seed or else in the calyx.

Enzymes. *Oxydase.*—In common with other seeds containing drying oils, oxydase is present and exerts its influence in the hardening of the oil. *Peroxydase* has been shown by Coupin [3] also to be present.

[1] Monatsh. Chem. 1887, **8**, 198.

[2] Arch. exp. Pharm. 1903, **49**.

[3] Compt. rend. 1925, **180**, 685.

Proteases.—Gorup-Besanes[1] and also Vines[2] have shown that hemp seed contains an especially active protease, essentially peptic, that digests fibrin to albumose and peptone but does not effect further changes.

Mineral Constituents.—The following analysis of the cake, constituting 5.27 per cent of the seed, is given by Wolff:[3]

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
20.28	0.78	23.64	5.70	1.00	trace	36.46	0.19	11.90	0.08

Minor Mineral Constituents. *Iron.*—Seed 210 mg. per kilo, dry basis (McHargue).[4]

Manganese.—Seed 34.5 mg. per kilo, dry basis (Wester).[5] Seed 165 mg. per kilo, dry basis (McHargue).[4]

Zinc.—Whole seed 82.8 mg. per kilo, air-dry basis (Bertrand and Benzon).[6]

Iodine.—None (Winterstein).[7]

[1] Sachs: Physiol. Plants. Oxford, 1887, p. 346.
[2] Ann. Bot. 1908, **22**, 103.
[3] Aschenanalysen. 1880, p. 109.
[4] J. Agr. Res. 1923, **23**, 395.
[5] Biochem. Z. 1921, **118**, 158.
[6] Bul. soc. hyg. aliment. 1928, **16**, 457.
[7] Z. physiol. Chem. 1918, **104**, 54.

WEED SEEDS OF THE BUTTERCUP FAMILY

(*Ranunculaceæ*)

Because of the presence of poisonous alkaloids, the fruits and seeds of this family, as well as the flowers, stems, leaves, and roots, are alike unsuited for food and fodder. Only one seed, that of black caraway or black cumin (*Nigella sativa* L.) used in Europe as a spice, is commonly classed with foods. Others, notably louse seed (*Delphinium Staphysagria* L.), are used in medicine or else yield alkaloids so used. Fruits and seeds of species belonging in four genera occur in European screenings: *Ranunculus* (buttercup), *Adonis* (pheasant's eye), *Delphinium* (larkspur), and *Nigella* (field black caraway). Most of these species have been introduced into the United States.

The occurrence of ranunculaceous seeds in grain, which fortunately is unusual in the United States but is too common in Europe, necessitates their careful removal and caution in feeding the screenings containing them. Farm animals in grazing carefully avoid buttercups and other acrid plants. This acridity is stated to disappear on curing.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *flower* is symmetrical both as to the petal-like sepals and petals in *Ranunculus*, *Adonis*, and *Nigella*; unsymmetrical, with one of the five conspicuous sepals and two of the four inconspicuous petals spurred, in *Delphinium*. Numerous one-seeded *achenes* are present in *Ranunculus* and *Adonis*; five many-seeded *capsules*, more or less united at the base, in *Nigella*; one many-seeded *capsule* in *Delphinium*.

The *achenes* of *Ranunculus* and *Adonis* occur as such in grain and screenings. These are brown, yellow, or green, flattened-ovate, and margined, with a beak at the apex and a prolongation at the base. *Seeds* only of *Nigella* and *Delphinium* are usually encountered. They are nearly or quite black, angular, often bent-conical, and in the case of *Delphinium* transversely wrinkled. Seeds of *Adonis* are green, the inner surface of the pericarp nearly black.

In all the genera the *embryo* is minute and embedded in the non-starchy endosperm.

COMPARATIVE MICROSCOPIC STRUCTURE.—Harz[1] and Senft[2] have made extensive studies of the group.

[1] Samenkunde. Berlin, 1885, p. 1063.

[2] Pharm. Prax. 1902, **1**, 65.

Pericarp.—In the pericarp of *Ranunculus* and *Adonis* there is a parenchymatous *hypoderm* containing oxalate *crystals* but only in *Ranunculus* are these conspicuous in the ripe fruit. The third layer in *Ranunculus* consists of longitudinal sclerenchyma *fibers* several thick; in *Adonis* this layer is made up of *stone cells*, each with a *crystal*. Both species have an *endocarp* composed of transverse fibers.

Spermoderm.—Two or three layers are present. *Delphinium* and *Nigella*, lacking the protection of a pericarp, have a strongly developed *outer epiderm* with thick cuticularized outer wall. In *Delphinium* these walls are warty and in addition the cells are radially elongated on the wrinkles; in *Nigella* the walls are smooth and the cells are uniformly conical. The *inner epiderm* in all four seeds has more or less porous or spiral-reticulated walls. These cells in surface view are nearly isodiametric-polygonal, approaching quadrilateral, in all the seeds but *Delphinium*, in which they are strongly elongated and arranged in groups having their end walls in a row. The *outer epiderm* of *Adonis* contains green contents.

Perisperm.—Largely obliterated.

Endosperm.—The cells are moderately thick-walled and contain *aleurone grains* up to 10 μ or over with one or more globoids.

TALL BUTTERCUP

Ranunculus acris L.

Fr. Renoncule. Sp. Ranunculo. It. Ranuncolo. Ger. Scharfer Hahnenfuss.

Of the species of buttercup indigenous to the United States several are weeds of local occurrence. *R. abortivus* L., for example, is troublesome in the writers' garden. None of these native species, however, appears at present to grow to such an extent in grain fields as to cause appreciable contamination of the threshed grain. A number of European weeds of the genus grow luxuriantly in sections. For example, *R. bulbosus* L. is abundant in New England but not in the West, whereas *R. acris* is quite widely distributed, being abundant in a number of grain-growing states where the introduction of the fruit in the grain itself is quite possible. In Europe *R. arvensis* L. is particularly troublesome and its fruit occurs in grain. Several of the species, including the last named, have exceedingly acrid juice said to disappear on curing for hay.

Only the tall buttercup is here described, but others have much the same microscopic structure.

MACROSCOPIC STRUCTURE.—Each flower has five short yellow *sepals*, five lustrous yellow *petals*, and numerous flattened beaked *pistils* which ripen into fruits (achenes). In this species the *achene* (fruit) (Fig. 176) is smooth (thus differing from *R. arvensis*, which has a number of soft bristles on the sides), bordered, oval or nearly round, and, measured with the curved beak at the apex and the prolongation at the base, reaches in extreme cases 5 mm.

The leathery pericarp usually adheres to the *seed*, which is erect and consists in great part of endosperm, the speroderm being thin and the embryo small, embedded in the endosperm at one end.

MICROSCOPIC STRUCTURE.—Harz[1] and Senft[2] describe the structure of *R. arvensis*. Our studies on *R. acris* confirm Harz' description, at least as regards the spermoderm. Senft's cross section is accurately drawn but his interpretation appears to be faulty.

Fig. 176.

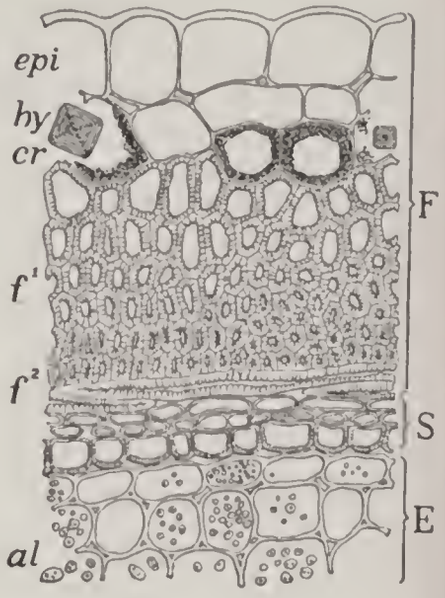


Fig. 177.

Fig. 176.—Tall Buttercup. Achene. ×5. (A.L.W.)

Fig. 177.—Tall Buttercup. Achene in cross section. *F* pericarp: *epi* epicarp, *hy* hypoderm with *cr* crystals, f^1, f^2 fibers. *S* spermoderm with two cell layers in loose contact and an inner layer with reticulated walls. *E* endosperm with *al* aleurone grains. ×160. (A.L.W.)

Pericarp. (Fig. 177, *F*).—Four layers are present: (1) *epicarp* (*epi*) of large longitudinally elongated cells with thin slightly wavy walls and stomata, (2) *hypoderm* (*hy*), one or more cells thick, each cell of the inner layer containing a single beautiful tetragonal crystal (*cr*) of calcium oxalate embedded in a matrix of brown disorganized chlorophyl, (3) *longitudinal fibers* (f^1), several thick, and (4) *transverse fibers* (f^2), one or two thick.

The *crystals* in cross section, although obscured by the contents of the cells, commonly are four- or six-sided in outline. When obtained free by scraping they commonly are square in outline and show as

[1] Samenkunde. Berlin, 1885, p. 1066.

[2] Pharm. Prax. 1902, **1**, 65.

crossing lines the four edges of a flattened pyramid or a combination of a pyramid and a prism.

In both layers of *fibers* the walls are thick and porous, but in the outer layer the size both of the fibers and of the lumen decreases from without inward.

Spermoderm (Fig. 177, *S*).—There are three layers: (1) *outer epiderm*, in surface view of more or less elongated cells with rounded ends and somewhat swollen walls, in loose contact, (2) *middle layer* much like the first, and (3) *inner epiderm* with finely reticulated radial and inner walls, the cells in surface view being isodiametric or moderately elongated, and polygonal, often with some of the sides so reduced as to be practically square.

Senft considers that the layer of porous cells is perisperm, whereas in other ranunculaceous seeds he considers, properly in our opinion, that the corresponding layer is the inner epiderm of the spermoderm. The cells of the middle layer of the spermoderm he also shows with beaded walls but elongated.

Perisperm.—A thin band of obliterated tissue is evident in some parts in cross section.

Endosperm (Fig. 177, *E*).—*Aleurone cells* with rather thick walls make up the endosperm. The *aleurone grains* vary from 3 μ in the outer layers to 10 μ or more further inward. One or more globoids are present.

Chief Structural Characters.—Achene smooth, margined, with curved beak and basal projection. Seed adherent to pericarp (in related genera free). Endosperm bulky, embryo small at one end.

Hypoderm with large tetragonal crystals; fibers in crossing layers. Spermoderm with inconspicuous outer epiderm (grotesque in related genera); inner epiderm with spiral reticulations.

PHEASANT'S EYE

Adonis æstivalis L.

Fr. Adonide. Ger. Sommeradonisröschen.

The showy red or yellow flowers of the various species of *Adonis* have led to their cultivation as ornamentals. In central Europe the pheasant's eye is a pest in grain fields. Adonidin, a poisonous alkaloid, renders the fruit objectionable in grain.

MACROSCOPIC STRUCTURE.—The achene (3 to 5 mm.) resembles that of the tall buttercup but is wrinkled and more irregular, the

inner surface of the *pericarp* is nearly black, and the *spermoderm* is peacock green with a metallic luster.

MICROSCOPIC STRUCTURE.—Senft [1] describes the histology of both pericarp and seed.

Pericarp.—As in the tall buttercup, four layers, although of different structure, are present: (1) *epicarp* of polygonal striated cells, hair scars, and stomata, (2) *hypoderm* of compressed parenchyma, several cells thick, containing small oxalate crystals, (3) brown *stone cells*, several thick, each containing a single large oxalate crystal, and (4) endocarp of transversely elongated sclerenchyma fibers.

Spermoderm.—The two epidermal layers are readily distinguished in surface view by their size and color: (1) the *outer epiderm* cells are irregularly polygonal, up to 100 μ in diameter and have peacock green contents; (2) *inner epiderm* cells are polygonal, often nearly square, up to 35 μ in diameter, and have beaded walls and olive green contents. A *middle layer* is evident in parts.

Endosperm and Embryo.—See Tall Buttercup.

CHIEF STRUCTURAL CHARACTERS.—Achene of buttercup type but more irregular and wrinkled. Pericarp black on inner surface. Seed free. Spermoderm peacock green.

Hypoderm with small crystals; stone cells with large crystals; endocarp fibers transversely elongated.

FIELD LARKSPUR

Delphinium Consolida L.

Fr. Dauphinelle. Sp. Espuela. It. Fior cappuccio. Ger. Feldrittersporn.

The field larkspur of Europe is mentioned by Gray as occurring in old grain fields of the eastern United States and by Selby [2] as having made its way as far west as Ohio. Whole pods of this species occur in Summer grain of central Europe and seeds in Winter grain, for which reasons Senft [3] has studied the histology. *D. Staphysagria* L., a native of southern Europe, is valuable in medicine because of its alkaloids. Its seed was studied by Senft because of its possible occurrence in grain of subtropical regions.

MACROSCOPIC STRUCTURE.—The striking difference of the flowers of larkspurs and columbines from buttercups, all classed in the same family, is a continual source of bewilderment to the layman.

[1] Pharm. Prax. 1902, **1**, 65.

[2] Ohio Agr. Exp. Sta. 1906, Bul. **175**, 325.

[3] Pharm. Prax. 1902, **1**, 65.

Evidence that the systematist, basing his classification on the less conspicuous parts, is sound is found in the microscopic structure.

All five *sepals* are usually bright blue, one being provided with a long spur, while the two of the petals are inconspicuous. The *pod* is many-seeded; the black *seeds* are 2 mm. long, angular, often bent-conical, and transversely wrinkled, suggesting the cones of conifers. As in buttercup seed, the *embryo* is minute and embedded in the upper end of the endosperm.

MICROSCOPIC STRUCTURE.—Harz [1] gives an accurate description of the microscopic structure of the seed and Senft [2] illustrates his description with a cross section of the seed and a surface view of the inner epiderm of the spermoderm.

Spermoderm.—Three layers are present: (1) *outer epiderm* with a greatly thickened (15 μ) warty cuticle, the cells of which on the wrinkles shoot up to a height of over 200 μ, often appearing fan-shaped in cross section, (2) *middle layer*, several cells thick, of longitudinally elongated brown cells in loose contact with swollen walls rounded at the ends, and (3) *inner epiderm* of longitudinally elongated cells, with fine spiral-reticulations, arranged in groups, those in the same group with end walls in a row.

Senft figures and describes a fourth layer which would appear to be either perisperm or the outer layer of the endosperm.

Perisperm and Endosperm.—Much as in buttercup.

CHIEF STRUCTURAL CHARACTERS.—Seed black, 2 mm., cone-like, transversely wrinkled.

Spermoderm with warty epidermal cells extended as fan-like outgrowths; inner epidermal cells elongated, spiral-reticulated.

According to Senft, the outer epiderm of the spermoderm of *D. Staphysagria* consists of prismatic cells reaching a height of 450 μ on the ridges and 280 μ in other parts, with greatly thickened walls and a cuticle provided with curious finger-like rods up to 30 μ long.

FIELD BLACK CARAWAY

Nigella arvensis L.

Fr. Nigelle. Ger. Ackerschwarzkümmel.

The genus *Nigella* is represented in horticulture by several species, known as love-in-a-mist, fennel flowers, etc., which are characterized by the hair-like branching involucre surrounding the blue, white, or

[1] Samenkunde. Berlin, 885

[2] Loc. cit.

yellow flowers. *N. sativa* L. is the black caraway or black cumin of Europe used to some extent as a flavor. The wild species, *N. arvensis*, grows in European grain fields, and the seed occurs in screenings.

MACROSCOPIC STRUCTURE.—The *seed* is much like that of larkspur, being black, angled, and over 2 mm. long, but is only granular on the surface and not transversely wrinkled, although the seeds of some other species of the genus are wrinkled.

MICROSCOPIC STRUCTURE. Spermoderm.—Harz [1] and Senft [2] both describe four layers. Since their inner layer is probably perisperm or outer endosperm, only three layers are here given: (1) *outer epiderm* of thick-walled cells extended beyond the surface as blunt-conical, non-warty papillæ, (2) *middle layer* of thin-walled more or less compressed parenchyma, and (3) *inner epiderm* of spiral-reticulated cells, in surface view polygonal with some of the sides so reduced as to appear square.

Perisperm and Endosperm.—As in buttercup.

CHIEF STRUCTURAL CHARACTERS.—Seed resembles larkspur seed but granular, not wrinkled.

Spermoderm with blunt-conical, non-warty papillæ.

[1] Samenkunde. Berlin, 1885, p. 1070.

[2] Pharm. Prax. 1902, **1**, 65.

SEEDS OF THE POPPY FAMILY

(*Papaveraceæ*)

Seeds of species of poppy, grown for food or oil production, or occurring as weed seeds in grain fields, are here described.

POPPY SEED

Papaver somniferum L. = *P. opiiferum* Forsk.

Fr. Pavot. Sp. Adormidera. It. Papavero. Ger. Mohnsamen.

The wild poppy (*P. setigerum* D.C. = *P. somniferum* var. *setigerum* Elk.) of Mediterranean countries is probably the progenitor of the poppy cultivated for opium and seed. It is believed to have originated in Greece or some neighboring country, during prehistoric times, whence it traveled to Asia Minor, Persia, and India. Not until the sixteenth century does it appear to have been known in China, where today, as well as elsewhere in Asia and various parts of Europe. it is extensively cultivated.

Two varieties or groups of cultural varieties appear to be well marked: the white-seeded (var. *album* D.C. = *P. officinale* Gmel.) and the black-, brown-, or blue-seeded (var. *nigrum* D.C. = *P. nigrum* Crantz = *P. opiiferum* Forsk.). The color of the blue poppy seed is optical, the contents of the pigment layer being brown as explained below.

In general it may be stated that the white-seeded varieties are preferred for opium production, and these are the varieties most commonly grown in India whether for opium or seed. The varieties grown in the Levant, Russia, France, and other parts of Europe for seed are more commonly blue or gray. In addition to their use in oil production the blue seed frequently is added to bread, to which it imparts a peculiar delicate flavor. Rolls with poppy seed sprinkled on the surface are often made by bakers both in Europe and America.

Poppy seeds are entirely free from opium.

MACROSCOPIC STRUCTURE.—Among the marked characters of the *flower* are the two sepals, the four conspicuous but delicate satiny petals, the numerous stamens. and the globular one-celled ovary with

usually twelve placentæ united to form partitions and as many radiating sessile stigmas united to form a flat projecting top. Dehiscence is commonly through small openings formed beneath the cap.

The *seeds* are minute, and as many as 2130 have been counted by Köhlreuter [1] in a single capsule. In form the half anatropous seeds (Fig. 178, I) are kidney-shaped with one end broader than the other and a marked notch in which are both the hilum and chalaza connected by a short raphe; in color they range from white through blue, gray, and brown to nearly black. Under a lens the surface is beautifully reticulated. The bent embryo (Fig. 178, II) with cotyledons slightly longer than the radicle is in the center of the fleshy endosperm.

FIG. 178.—Poppy Seed. I seed. II embryo. ×16. (A.L.W.)

MICROSCOPIC STRUCTURE.—Because of its small size and the compression of the layers, poppy seed is not easily studied.

Spermoderm (Fig. 179, *S*; Fig. 180).—The earlier authors overlooked certain layers of the spermoderm and later authors are not agreed as to whether there are five or six. Winton [2] finds but five layers as follows: (1) *outer epiderm* (*ep*) of low but enormously broad cells with thin wavy

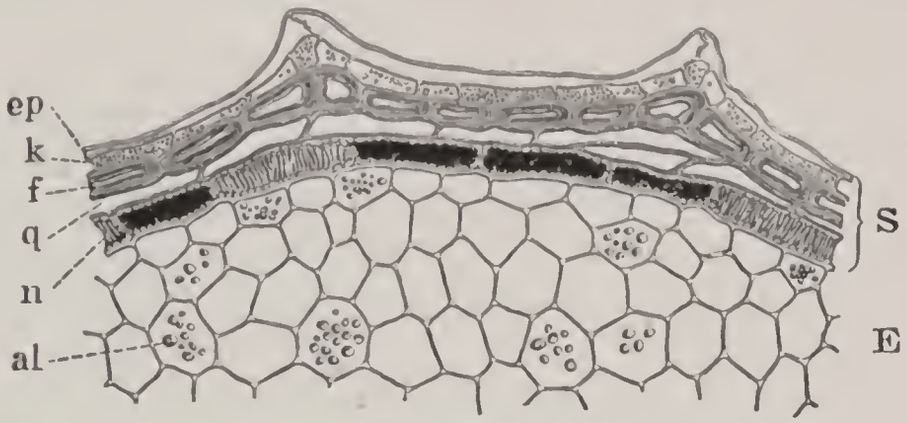


FIG. 179.—Poppy Seed. Cross section. *S* spermoderm: *ep* outer epiderm, *k* crystal layer, *f* fiber layer, *q* cross cells, *n* pigment cells. *E* endosperm containing *al* aleurone grains. ×160. (A.L.W.)

walls, corresponding to the ribs of the seed, (2) *crystal layer* (*k*) of thin-walled cells containing granular crystals of calcium oxalate, (3) *fiber layer* (*f*), the individuals being broad (up to 40 μ) with thick walls, (4) *cross cells* (*q*) with brown walls, and (5) *pigment cells* (*n*) with spiral reticulations and dark contents (*pig*).

[1] Mach: Landw. Vers.-Stat. 1902, **57**, 421.

[2] Connecticut Agr. Exp. Sta. Rep. 1903, p. 195.

The sixth or innermost layer, mentioned by several authors (doubtless on the authority of one), is not evident in a number of mature seeds examined by us.

The *color* of the gray seeds has been shown by A. Meyer [1] to be optical and due to the crystals of the second layer. When these are dissolved in acid the seed is brown. The apparent blue of the sky and of the iris of blue eyes is due to a similar interference phenomenon.

Beneath the ribs the *fibers* are thicker, contributing in large part to the prominence of the reticulations.

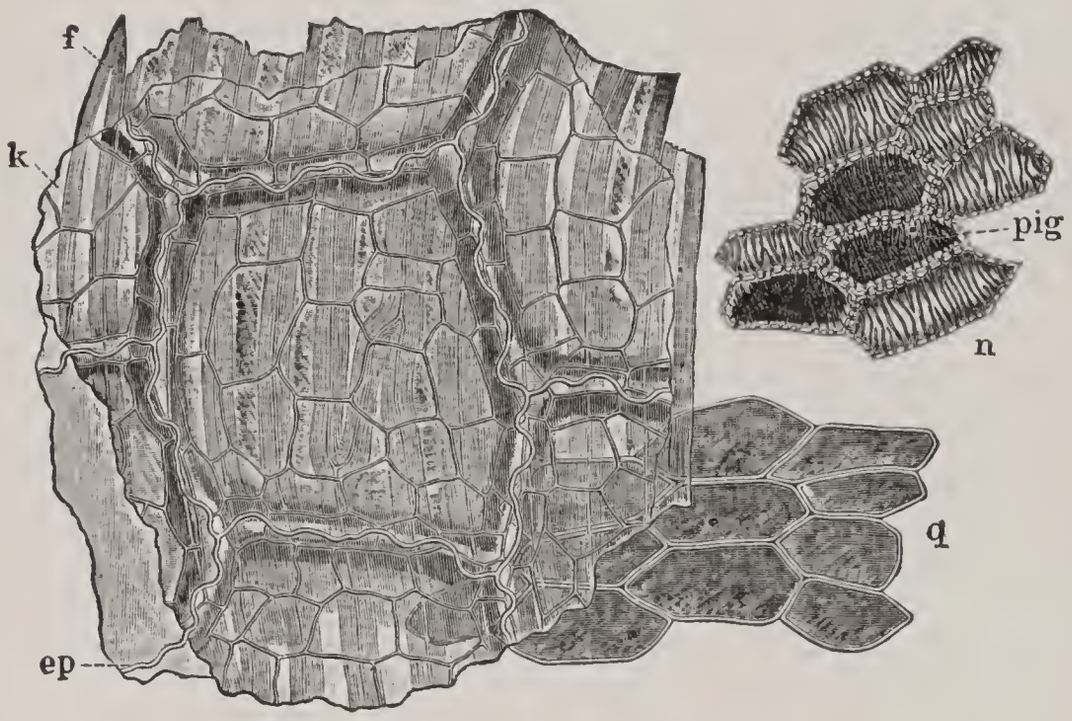


FIG. 180.—Poppy Seed. Spermoderm in surface view. *ep* outer epiderm; *k* crystal layer; *f* fiber layer; *q* cross cells; *n* pigment cells containing *pig* pigment. ×160. (A.L.W.)

Endosperm (Fig. 179, *E*).—Typical parenchyma with *aleurone grains* reaching a maximum of 7 μ in the inner layers makes up the bulky endosperm.

Embryo.—The tissues are characterless. Only one layer of *palisade cells* is present in the cotyledons, the cells being slightly elongated. The contents are like those of the endosperm.

CHIEF STRUCTURAL CHARACTERS.—Seeds small, kidney-shaped, reticulated, blue-gray. Endosperm bulky.

Spermoderm with large, thin-walled outer epidermal cells corresponding to reticulations, crystal cells, broad fibers, brown cross cells, and reticulated pigment cells. Endosperm and embryo with aleurone grains (7 μ).

[1] Wissenschaftliche Drogenkunde. Berlin, 1891, p. 160.

CHEMICAL COMPOSITION.—No American analyses of the seed or cake are available. The following limits of composition are based on European analyses of poppy seed of Asiatic and Continental origin quoted by Dietrich and König[1] and Mach:[2]

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.....	3.00	12.60	23.45	9.50	4.77	3.42
Max.....	14.70	23.12	55.62	36.14	6.16	7.89*

* In a sample of Smyrna seed Dietrich, Hesse, and Greitherr found 13.97 per cent, doubtless due to sand.

More recent and more complete analyses are given in Mach's monograph referred to above, as follows:

Composition of Poppy Seed (Mach)

	Water	Protein	Pure protein	Amines, amides, etc.	Fat	N-f. ext.	Pentosans	Fiber	Ash, total	CO_2 in ash	Sand
	%	%	%	%	%	%	%	%	%	%	%
E. Indian.....	4.50	22.68	21.60	1.08	48.02	9.81	3.44	5.18	7.14	0.77	0.37
Levantine.....	4.28	20.28	18.42	1.86	50.65	10.58	3.05	5.38	6.61	0.83	0.22
Turkish.....	3.87	20.35	18.88	1.47	51.40	9.50	3.20	5.64	6.84	0.80	0.45

Poppy Seed Cake.—The following limits are from a compilation by Mach:[2]

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.....	4.3	24.4	3.8	8.5	4.9	10.1
Max.....	17.7	41.6	17.1	29.6	22.8	14.5

The limits and averages obtained in the analysis of 143 samples at Prussian experiment stations from 1892 to 1896 are: protein 29.3 to 40.9, aver. **35.72**; fat 5.6 to 16.7, aver. **12.22** per cent.

The composition of the cake of more recent origin is shown by Mach's own analyses of 4 samples, 2 of French cake, the first from Turkish and

[1] Zusam. Verd. Futterm. 1891, I, 574.

[2] Landw. Vers.-Stat. 1902, **57**, 419.

the second from Levantine seed, and 2 of German cake, both from East Indian seed:

Composition of Poppy Seed Cake (Mach)

	Water	Protein	Pure protein	Fat	N-f. ext.	Pento-sans	Fiber	Ash, total	CO_2 in ash	Sand
	%	%	%	%	%	%	%	%	%	%
Freneh:										
I.....	10.05	37.29	35.22	8.11	14.38	5.32	12.35	13.49	0.99	2.59
II.....	11.20	32.03	30.81	5.65	21.26	5.01	11.13	14.88	1.16	3.71
German:										
I.....	8.48	40.47	39.04	8.63	15.81	5.58	9.23	13.26	1.46	1.02
II.....	8.46	38.35	36.46	13.36	16.87	5.52	7.95	10.83	1.04	0.76

Proteins.—The poppy being the only species of the family yielding a commercial oil seed, the lack of data on the proteins leaves an unfortunate gap in the study of group characters and their interrelations. The unique structure of the seed and its content of calcium oxalate suggest that possibly the proteins may be unusual.

Oil.—The degree of unsaturation as indicated by the iodine number places poppy seed oil intermediate between walnut and hemp seed oils. Like both of these the cold pressed oil is edible. Because of its drying properties, as well as for other reasons, it is valuable for artists' colors.

Physical and Chemical Values.—Tolman and Munson [1] appear to be the only American chemists who have recorded data on authenticated samples. From their compilation and figures given by Lewkowitsch and others the following limits are taken:

Values of Poppy Seed Oil

	Sp. gr. 15.5° C.	Refractive index 25° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer
						° C.
Min.....	0.9239	1.4730	71	189	130	15
Max.....	0.9370	1.4750	89	197	158	17

Cold pressed oil, when freshly prepared, usually has an iodine number of 130 to 140 and an acidity calculated as oleic of less than 1 per cent. Higher figures for iodine number were obtained by Utz [2] in extracted oil.

[1] U. S. Dept. Agr., Bur. Chem. 1903, Bul. **77**, 42.
[2] Chem. Ztg. 1903, **27**, 1177; 1904, **28**, 257.

The commercial oil, particularly that designed for technical purposes, may contain upward of 20 per cent of acid.

Composition.—The percentages of individual acids in the liquid acid of poppy seed oil, as given by Hazura and Grüssner,[1] are as follows:

	%
Oleic acid	30
Linolic acid	65
Linolenic acid	5
	100

These have been often quoted and often disputed. Tolman and Munson found 6.67 per cent of solid acids in the total fatty acids.

Carbohydrates.—Results on pentosans and fiber are given in Mach's analyses above. Little is known about the other carbohydrates.

Phosphorus-Organic Compounds. *Lecithin.*—Schulze and Frankfurt [2] found 0.25 per cent of lecithin in the dry matter. Mach,[3] following Schulze's method, obtained 0.94 per cent, calculated to the same basis.

Phytin and *Nuclein*, like protein, are subjects for study.

Mineral Constituents.—Mach analyzed the ash of the 3 samples of poppy seed and the 4 samples of cake, the proximate analyses of which are given in two of the foregoing tables, with the following minimum and maximum results, calculated in percentages of the pure ash:

Composition of the Ash of Poppy Seed and Poppy Seed Cake (Mach)

	Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3 †	P_2O_5	SO_3	SiO_2	Undet.
	%	%	%	%	%	%	%	%	%	%
Seed:										
Min.	5.56	10.85	0.70	32.00	8.65	1.80	32.10	3.60	1.05	3.60
Max.	6.36	12.25	0.90	34.90	9.05	2.65	35.05	3.75	1.70	4.85
Cake:										
Min.	9.03	12.05	0.65	32.95	7.70	2.80	29.55	3.30	1.00	2.10
Max.	10.78	14.40	0.80	36.10	9.40	3.50	34.20	3.80	2.70	3.85

* In material ashed. † Includes Al_2O_3.

Calcium Oxalate.—Of special interest is the high percentage of lime attributable in considerable part to the presence of calcium oxalate crystals. The location of this salt is clearly shown in the foregoing description of the histological structure.

Mach[3] found 1.62 per cent of oxalic acid ($C_2H_2O_4$) in East

[1] Monatsh. Chem. 1888, **9**, 180.
[2] Landw. Vers.-Stat. 1894, **43**, 312.
[3] Loc. cit.

Indian poppy seed equivalent to 2.63 per cent of calcium oxalate ($CaC_2O_4 + H_2O$). The equivalent calcium oxide is 1.01 per cent or a trifle over half of the whole amount (2.22 per cent) found by him in the ash, calculated in percentage of the unburned material. The percentage of carbon dioxide equivalent to 2.63 per cent of calcium oxalate is 0.791, which corresponds almost exactly with the amount of carbon dioxide (0.77 per cent) present in the ash of the sample, calculated to the unburned material. It thus appears that the carbon dioxide of the ash is derived from the calcium oxalate which burns to the carbonate.

Minor Mineral Constituents. *Manganese.*—Seed 30 to 31 mg. per kilo, dry basis (Wester).[1]

[1] Biochem. Z. 1921, **118**, 158.

SEEDS OF THE MUSTARD FAMILY

(*Cruciferæ*)

The members of the mustard family besides furnishing us with some of the most valuable pot herbs (cabbage, Brussels sprouts, kale, cauliflower, kohl rabi), root vegetables (turnip, radish), and the root condiment horse-radish, yield seeds with high oil and protein content well suited for oil production and feeding and often with pungent principles, valuable alike as drugs and condiments. (See Black Mustard, Sarepta Mustard, Brown Mustard, Charlock, Indian Mustard, and White Mustard under Spices, Volume III.)

COMPARATIVE MACROSCOPIC STRUCTURE.—The family is characterized morphologically by the *flowers* with four inconspicuous sepals and with four petals, commonly yellow or white, symmetrically arranged forming a cross, the *pod* usually two-celled and opening by two valves, and the irregularly rounded or ovoid campylotropous seeds with a thin shell-like spermoderm and a still thinner endosperm.

The genera here considered may be classified as follows: (1) pod round, jointed, indehiscent: *Raphanus*; (2) pod round, long or short, dehiscent by valves: *Eruca*, *Brassica*, *Sisymbrium*, *Erysimum*, *Barbarea*, *Camelina*; (3) pod flat, dehiscent by valves: *Capsella*, *Lepidium*, *Thlaspi*. In the subsequent tables they are arranged in order here given.

In color the seeds range from light yellow to dark brown or black, in size from less than 1 mm. to 4 mm. or more. Certain of the true mustards (*Brassica*) have seeds with more or less marked reticulations visible under a lens of moderate power, such as a watch-maker's lens, magnifying about two diameters, while field pennycress (*Thlaspi*) has distinct and hare's ear (*Erysimum*) indistinct striations parallel with the axes of underlying radicle and cotyledon.

An important morphological detail is the arrangement of the cotyledons with respect to the radicle. If these present their edges to the radicle ($= \circ$) they are accumbent, if their faces ($\parallel \circ$) they are incumbent, if folded so that the radicle is in the angle ($\ll \circ$) they are conduplicate. De Candolle divides the genera into five groups: (1) *Pleurorhizeæ* with accumbent cotyledons, (2) *Notorhizeæ* with incumbent cotyledons, (3) *Orthoploceæ* with conduplicate cotyledons, (4) *Spirolobeæ* with spiral embryo, and (5) *Diplocolobeæ* with double folded cotyledons, the last two groups not being represented in this work. One objection to this

classification is that it dismembers the genus *Lepidium*, one species having accumbent cotyledons, the other incumbent.

Some of the important macroscopic characters of the seeds here considered appear in the table on the following page. The maximum diameters given are the longest diameters of the largest seeds, which are, in our experience, more definite and convenient than average diameters.

COMPARATIVE MICROSCOPIC STRUCTURE.—Cross sections are best cut dry, holding the seed between pieces of cork. If mounted in alcohol the contents of the epidermal cells may be seen with little if any change. Cautious addition of water to such mounts permits a study of the swelling mucilage.

The preparation of satisfactory cross sections, which in the study of the whole seed, even for an expert, requires time and patience, in the examination of oil cake is quite impracticable. For the diagnosis of oil cakes and meal it is therefore necessary to depend on surface preparations variously treated as described in a subsequent section. A table showing the chief characters in surface view is given herewith. This should be consulted in connection with a perusal of the following general discussion of the different tissues.

Spermoderm.—Normally four layers are present: (1) *outer epiderm* of polygonal cells containing mucilage, (2) *subepiderm* of thin-walled or collenchymatous (or collenchyma-like) cells, (3) *palisade layer* with inner and radial walls more or less thickened, and (4) *parenchyma*, more or less compressed, including the *inner epiderm* which is seldom differentiated in the ripe seed.

In many cruciferous seeds the first two layers at maturity are so compressed as to show no structure in either cross section or surface view. Much emphasis has been laid on this character—in fact the group may be classified on this basis into two sub-groups—but such a classification is not satisfactory because unripe seeds may show structure lacking in the mature seeds, and even mature seeds under favorable conditions show cell structure, also because cross sections, which are impracticable as above noted, are essential to definitely decide whether or not the two layers are cellular.

(1) *Epiderm.*—When evident the cells in cross section are quadrilateral, varying in height with the species. In surface view they are polygonal, the walls appearing thin and characterless, beaded, or swollen. Only in hare's ear are the pores forming the beads ordinarily seen in cross section (see table).

The contents are mucilaginous, presenting when evident a more or less characteristic appearance in alcohol and especially after adding water, as may be seen by consulting the cuts on the following pages.

MACROSCOPIC CHARACTERS OF CRUCIFEROUS SEEDS

	Color	Shape	Max. longest diam.	Markings (under lens)	Cotyledons
			mm.		
Radish (*Raphanus spp.*)	red-yellow	irregular	4.0	faint reticulations	conduplicate
Rocket (*Eruca sativa*)	yellow, etc.	irregular	2.0	none	conduplicate
Black Mustard (*Brassica nigra*)	dark brown	globose	1.7	fine reticulations	conduplicate
Sarepta Mustard (*B. Besseriana*)	medium brown	globose	2.0	coarse reticulations	conduplicate
Charlock (*B. arvensis*)	black	globose	1.5	none, dull	conduplicate
Palai (*B. rugosa*)	brown	globose	1.7	fine reticulations	conduplicate
White Mustard (*B. alba*)	light buff	globose	3.0	faint reticulations	conduplicate
Dissected Mustard (*B. dissecta*)	red-brown	globose	3.0	reticulations	conduplicate
Indian Mustard (*B. juncea*)	red-brown	globose	2 or 2.5 *	marked or faint ret.*	conduplicate
Tori (*B. Napus dichotoma*)	dark brown	globose	2.2	none, granular	conduplicate
German Rape (*B. Rapa oleifera*)	brown	globose	2.2	reticulations	conduplicate
Common Rape (*B. Napus oleifera*)	brown	globose	2.5	faint reticulations	conduplicate
Sarson (*B. Campestris Sarson*)	yellow or brown *	globose	2 or 3.0 *	faint reticulations	conduplicate
Hedge Mustard (*Sisymbrium officinale*)	light brown	elongated †	1.3	none	incumbent
Tumbling Mustard (*S. altissimum*)	brown-yellow	truncated †	1.3	none	incumbent
Hare's Ear (*Erysimum orientale*)	dark brown	elongated †	2.8	faint striations	incumbent
Winter Cress (*Barbarea vulgaris*)	light brown	elongated †	1.2	none	accumbent
False Flax (*Camelina sativa*)	light brown	elongated †	2.3	none	incumbent
Shepherd's Purse (*Capsella Bursa-pastoris*)	light brown	elongated †	1.3	none	incumbent
Wild Peppergrass (*Lepidium virginicum*)	light brown	elongated †.	1.5	none	accumbent
Field Pennycress (*Thlaspi arvense*)	dark brown	flattened	2.0	marked striations	accumbent

* According to variety. † Ridge over radicle.

D'Arbaumont's investigation[1] seems to show that the mucilage is formed from cell contents, not from cell wall as has been previously held. If such is the case, it is hard to explain the flow outward of mucilage from between the middle lamella and the inner thickened wall in *Capsella* and *Lepidium*.

(2) *Subepiderm.*—When present the cells are ordinarily thin-walled and characterless; in white mustard and dissected mustard, however, they are collenchymatously thickened at the angles, rendering the layer conspicuous and highly important in diagnosis.

(3) *Palisade Layer.*—It is in this layer that differentiation is most striking. The term palisade layer is perhaps unfortunate since in certain species the cells are much broader than high, and in three seeds, hedge and tumbling mustard (*Sisymbrium*) and hare's ear (*Erysimum*), even the thickening of the radial wall is absent. In radish (*Raphanus*), rocket (*Eruca*), mustards and rape (*Brassica*), and field pennycress (*Thlaspi*) the cells are strongly palisade-shaped with thickened inner and radial walls, varying in color from light yellow (white and dissected mustards, sarson) to dark brown (black, Sarepta, and Indian mustards, charlock, rapes). In certain species the height of the cells varies, thus forming the characteristic dark network seen in surface view of the mustards and the dark bands of field pennycress. Usually these reticulations of the palisade layer also cause reticulations of the seeds; in white and dissected mustard, however, owing to the somewhat rigid epiderm and subepiderm, the reticulations do not appear also on the surface. Only the inner part of the radial wall is ordinarily thickened, the ratio of thickened to thin wall varying with the species.

The size of the cells in surface view (see table) varies sufficiently in the genus *Brassica* to be of great aid in diagnosis, and still greater variation occurs in other genera.

The ratio of breadth of lumen to breadth of double walls in surface view differs greatly. In common and German rape there is sufficient difference to distinguish the two, although the lumen is not in these or any other members of the genus much broader than the double walls, whereas in all but the last of the seven seeds at the bottom of the table it is several times as broad.

Contents are not conspicuous or interesting except in charlock (*Brassica arvensis*), where the black material responds to a remarkable color reaction with acid chloral hydrate, and in winter cress (*Barbarea*), where each cell contains a fine crystal of calcium oxalate.

(4) *Parenchyma* (Pigment Cells).—One or more layers of thin-walled, more or less compressed cells form the inner spermoderm. Dark con-

[1] J. mic. 1891, **15**, 212; Bul. soc. bot. France, 1891, **38**, 67.

tents may be present or the walls impregnated with the coloring matter, hence the name " pigment cells," which is not applicable when the walls and contents are colorless. Field pennycress (*Thlaspi*) has an inner layer of large cells which is doubtless inner epiderm. As a rule the parenchyma layer is neither distinctive nor interesting.

Endosperm.—It is remarkable that neither endosperm nor embryo differs materially in any of the species from the type. The endosperm consists of a single layer of *aleurone cells* and an inner tissue of *compressed cells*. The aleurone cells are quite like those of the cereals and the *aleurone grains* are so small as to leave some uncertainty as to their being true to name. Gram [1] notes that in one species (*Brassica dichotoma*) the cells form commonly a double layer comparable with that of barley, but this we do not confirm.

Embryo.—Cotyledons and radicle are not only alike in general structure throughout the family but show so little difference in detail, such as size and character of aleurone grains, as scarcely to be worthy of notice. In cross sections of the cotyledons several rows of *palisade cells* are seen on the inner sides and several of more or less nearly isodiametric cells on the outer sides with rows of *procambium bundles* in the tissue between. In surface view of the *epiderm* the division into daughter cells, later becoming stomata, is evident.

The *aleurone grains* vary up to 20 μ, being smallest in the outer layers. In form they are isodiametric or elongated, the latter measured through the longer axis reaching the maximum size stated. Numerous globoids are the only visible contents of the grains. The arrangement of some large grains in the narrow palisade cells produces a curious partitioned or jointed appearance.

Of special interest are the *myrosin cells* discovered by Gruinard.[2] These contain grains without globoids, the whole cell being more refractive than the adjoining cells and giving stronger protein reactions as noted under black mustard. The cells occur in parts of the plant other than the seed but without the contents assuming the form of grains. Gram [1] shows myrosin cells in the cotyledons of rape; we find them more often in the radicle, black and white mustard being suitable material for their study.

MICROSCOPY OF CRUCIFEROUS PRODUCTS.—Cross sections of the whole seed may be cut dry and examined first in alcohol and then after adding water. Surface preparations of the seed or fragments of the hulls may be picked out with forceps from the cake and examined without treatment, noting the color, the nature of the markings if pres-

[1] Landw. Vers.-Stat. 1898, **50**, 449.

[2] J. Bot. 1893, **7**.

MICROSCOPIC CHARACTERS OF CRUCIFEROUS SEEDS IN SURFACE VIEW

	Palisade cells					Subepiderm	Epiderm	
	Color	Max. diam.	Walls	Lumen broader or narrower than double walls	Markings		Walls	Mucilage
		μ						
Radish (*Raphanus spp.*)	medium	18	thick	broader	netted	thin-walled	thin	obscure
Rocket (*Eruca sativa*)	dark	.....	thick	equal	none	not evident	thin	axial
Black Mustard (*Brassica nigra*)	dark	20	thick	narrower	netted	thin-walled	beaded	layers
Sarepta Mustard (*B. Besseriana*)	dark	27	thick	narrower	netted	thin-walled	beaded	concentric
Charlock (*B. arvensis*)	black *	15	thick	narrower	none	thin-walled	beaded	columns
Palai (*B. rugosa*)	medium	20	thick	narrower	netted	not evident	beaded	
White Mustard (*B. alba*)	light	25	thick	equal	netted	collenchyma	beaded	concentric
Dissected Mustard (*B. dissecta*)	dark	25	thick	equal	netted	collenchyma	beaded	concentric
Indian Mustard (*B. juncea*)	dark	27	thick	narrower	netted	not evident	obscure	
Tori (*B. Napus dichotoma*)	dark	25	thick	varies	netted	not evident	obscure	
German Rape (*B. Rapa oleifera*)	dark	35	thick	narrower	netted	obscure	obscure	
Common Rape (*B. Napus oleifera*)	dark	35	thick	equal	none	obscure	obscure	
Sarson (*B. campestris Sarson*)	various	32	thick	narrower	none	not evident	obscure	
Hedge Mustard (*Sisymbrium officinale*)	medium	.....	thin	broader	none	not evident	thin	axial †
Tumbling Mustard (*S. altissimum*)	medium	30	thin	broader	none	not evident	thin	axial †
Hare's Ear (*Erysimum orientale*)	dark	55	thin	broader	none	not evident	toothed	axial †
Winter Cress (*Barbarea vulgaris*)	medium	.....	thick	broader ‡	none	present	thin	layers
False Flax (*Camelina sativa*)	medium	100	thick	broader	none	not evident	thin	axial §
Shepherd's Purse (*Capsella Bursa-pastoris*)	medium	60	thick	broader	none	not evident	medium	axial §
Wild Peppergrass (*Lepidium virginicum*)	medium	40	thick	broader	none	not evident	swollen	axial §
Field Pennycress (*Thlaspi arvense*)	dark	55	thick	narrower	bands	obscure	obscure	

* Black contents. † Conical when escaped from cell. ‡ Each cell contains crystal or crystal cluster. § Finger-like when escaped from cell.

ent, the size of the palisade cells and the ratio of lumen to cell wall, and the formation of the mucilage, if evident. The residues of the cake after extraction with ether or gasoline or else the crude fiber may also be examined.

The tables showing the general characters of the group are designed as a guide, supplementing the description under each seed. In some cases where the distinctions are fine or unsatisfactory, positive identification may not be possible without knowledge of some of the circumstances pertaining to the material, such as the place of growth or market conditions. The group is a difficult one; excepting the mustards it is comparatively little known in the United States, although of much importance in Europe, India, and other parts of Asia.

COMPARATIVE CHEMICAL COMPOSITION.—Seeds of the same species differ so widely in fat content and the ratio of fat to protein as to render classification on either basis difficult. Rape seed is in general the richest in fat and the poorest in protein of the *Brassica* group, but some of its varieties do not show these characteristics in marked degree.

Förster in his monograph on rape cake [1] states that the larger the seed the richer in fat, the smaller the seed the richer in protein. It seems also probable that the rule can be extended to include fiber, which is higher in the smaller and lower on the larger seeds. The rule thus extended in the case of protein and fiber appears to depend in large part on the percentage of hulls in the whole seed which decreases as the seed increases in size. As regards protein this explanation does not hold, as the hulls contain less protein than the whole seed.

It would seem that Förster's rule should apply in comparing seeds of different species, at least of the genus *Brassica*, and it does appear to apply to seeds of common rape, German rape, and black mustard, the maximum diameters of which are respectively 2.5, 2.2, and 1.7 mm. It does not apply, however, to seeds if white mustard, reaching 3 mm. in diameter, is included in the comparison, since the protein content of this exceptionally large seed is nearly as high as, and the fat content actually lower than, those of the small seed of black mustard; hence the rule must be limited to seeds of the same species and perhaps of the same variety.

Regardless of size, high fat is usually associated with low protein and fiber and vice versa. The average fat content of rape seed is more than double the average protein content while the average fat content of black mustard is only about 20 per cent higher than the average protein content. Individual analyses show much greater spreads.

[1] Landw. Vers.-Stat. 1898, **50**, 385.

Proteins.—The chief protein of seeds of the family appears to be a globulin but data are exceedingly limited.

Fixed Oil.—Studies of values and composition have been confined chiefly to common and German rape and it is often uncertain which seed furnished the oil. The figures given under common rape are tentatively considered as applying to both. The iodine number varies both sides of 100. The chief acid, amounting to nearly 60 per cent of the total acids, is erucic.

Pungent Principles.—The discovery of the *myrosin cells* in seeds of certain species of *Brassica* marks a beginning in the correlation of microscopic phenomena and chemical changes taking place in the seeds, on moistening, through the action of the ferment myrosin. Acting on *sinigrin* or potassium myronate (present in most mustards except white) allyl isothiocyanate or volatile mustard oil is formed; acting on *sinalbin* (present in white mustard) sinapin acid hydrosulphate, glucose, and sinalbin mustard oil are formed. Of these products, volatile mustard oil and sinalbin mustard oil are pungent.

Since the presence of pungent principles in considerable amount unfits a seed or cake for cattle feeding, only those seeds are described in this section which contain them in relatively small amounts.

These constituents on the other hand, which render the seeds objectionable as cattle foods, are the very ones which give the mustards value as spices, hence those species characterized by the presence of either sinigrin or sinalbin in considerable amounts—the mustards—are reserved for description in Volume III, where also are described the principles themselves, namely: sinigrin under Black Mustard and sinalbin under White Mustard.

BLACK MUSTARD, SAREPTA OR BROWN MUSTARD, INDIAN MUSTARD, WHITE MUSTARD, CHARLOCK

Descriptions under Spices, Volume III.

WILD RADISH

Raphanus Raphanistrum L.

Fr. Ravenelle. It. Rafano. Ger. Hederich.

Jointed or white charlock are other English names for this weed. It has also been placed in the genus *Raphanistrum* with various specific names (*Lampsana* Gærtn., *segetum* T., *arvense* Wallr., *innocuum* Fl. Wett.). To add to the confusion, some botanists have held that

Raphanus sativus L., the garden radish, is but a variety derived by cultivation, which is further discussed under that head.

Wild radish is a European weed introduced in parts of the United States, although as yet it is not abundant. It is said to be especially noxious. Seeds occur in European oil cake.

MACROSCOPIC STRUCTURE.—Wild radish *flowers* are pale yellow, becoming lighter and often purplish. Unlike that of the garden radish, the long, tapering, beaked, and indehiscent *pod* is so deeply constricted as to break into several one-seeded joints. The *seeds* resemble somewhat those of white mustard but are larger (up to 4 mm.) more ellipsoidal, and of a reddish yellow color. They are very indistinctly reticulated under a lens.

MICROSCOPIC STRUCTURE.—Gram [1] finds the structure of the spermoderm and endosperm to be as follows:

Spermoderm.—All four layers of a normal cruciferous seed are represented: (1) *outer epiderm* with broad but low cells without visible mucilage, (2) *subepiderm* of two layers of thin-walled cells as large as those of the epiderm, (3) *palisade cells* with breadth of lumen about equaling or exceeding that of the double walls and thickened inner and radial walls of irregular height forming a network, and (4) *parenchyma*.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—An analysis of the seed as given by Dietrich and König [2] follows:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
7.12	23.60	25.56	22.17	10.13	11.42

Fatty Oil.—The following figures are due to Grimme:[3] specific gravity at 15° C. 0.9186, refractive index at 25° C. (recalculated) 1.4704, solidifying point −13 to −14° C., saponification number 176.0, iodine number 105, ester number 160, fatty acids 94.33 per cent, acid number 16.0 (equivalent oleic acid 8.5 per cent), and solidifying point of fatty acids 11 to 12° C.

[1] Landw. Vers.-Stat. 1898, **50**, 449.
[2] Zusam. Verd. Futterm. 1891, **1**, 570.
[3] Chem. Rev. Fett-Harz-Ind. 1912, **19**, 102.

CHINESE RADISH

Raphanus sativus L. var. *oleiferus* Reichenb.

Ger. Chinesischer Oelsenf.

This variety of the common or garden radish has been given various specific and varietal names under the genus *Raphanus*. It is grown as an oil seed.

Harz [1] finds that the *seed* (up to 4.5 mm.) is somewhat larger than that of the garden radish but otherwise has the same general and microscopic structure as both the garden and wild radish.

CHEMICAL COMPOSITION.—The following analyses of the seed and cake on the water-free basis are given by Dietrich and König:[2]

	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%
Seed:					
I	19.85	32.65	45.72		3.78
II	26.44	50.05	19.55		3.96
Cake	38.04	8.09	35.17	8.59	10.11

ROCKET

Eruca sativa Lam. = *Brassica Eruca* L.

Fr. Roquette. It. Ruchetta. Ger. Rauke.

Although cultivated for salad and greens in southern Europe, especially in France, rocket grows as a weed in Europe, in India, and (sparingly) in America, and the seeds occur in rape cake.

MACROSCOPIC STRUCTURE.—The *pods* vary up to 2.5 cm. long, one-third being beak. The ellipsoidal *seeds* are usually yellow, also reddish yellow, or mottled, smooth, about 2 mm. long. As in the mustards the *cotyledons* are conduplicate.

MICROSCOPIC STRUCTURE.—Harz [4] notes certain details of structure and Gram[3] gives cuts of a cross section and the elements in surface view showing the following structure:

[1] Samenkunde. Berlin, 1885, p. 945.
[2] Zusam. Verd. Futterm. 1891, **1**, 570, 658.
[3] Landw. Vers.-Stat. 1898, **50**, 449.
[4] Samenkunde. Berlin, 1885, p. 943.

The *outer epiderm* contains mucilage with a central column. In surface view each cell appears to be thick-walled owing to a margin on the outer walls. The *subepiderm* is lacking or of compressed cells. *Palisade cells* of the rape type with inner portion thick-walled (lumen about equaling the double walls) form the third layer; these as well as the contents of the *inner parenchyma* are colored brown, varying in shade.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—Hals and Gram,[1] who have studied the composition of the seed and cake, state that the oil is used as a salad oil in southern Europe and the cake for cattle food in Norway. The average of 4 of their analyses of the cake follows:

Composition of Rocket Cake (Hals and Gram)

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
10.53	39.50	2.53	29.85	8.74	8.85

Harz[2] states that the oil content ranged from 30 to 33 per cent.

Fatty Oil.—Grimme,[3] who found by ether extraction 32.2 per cent of oil in the seed, gives the following values of the product thus obtained: specific gravity at 15.5° C. 0.9198, refractive index at 25° C. (recalculated) 1.4705, solidifying point −8 to −10° C., saponification number 175.4, iodine number 101.8, ester number 171.4, fatty acids 94.24 per cent, acid number 3.0 (equivalent oleic acid 1.51 per cent), and solidifying point of fatty acids 8 to 10° C. In commercial samples of the oil the iodine number ranged from 96.8 to 106.8 and the acid number from 2.6 to 8.6.

PALAI

Brassica rugosa Prain.

According to Prain, other Indian names for this plant are palangi, pahari-rái, badisha-lai, and bhotiya-lai. It is cultivated chiefly in Nepal where more commonly the leaves are utilized for food than the seeds for oil.

Vilmorin refers to it as "Chinese cabbage-leaved mustard." It is said to have been introduced from Thibet. Prain considers it a sub-

[1] Landw. Vers.-Stat. 1909, **70**, 307.

[2] Samenkunde. Berlin, 1885, p. 944.

[3] Pharm. Ztg. 1912, **57**, 520.

species under *B. juncea* Hook. f. et Thom. and suggests that it may be the variety grown extensively by the Chinese for the leaves which are dried in the sun and eaten with rice.

MACROSCOPIC STRUCTURE.—In each two-valved, short-beaked *pod* (up to 3.8 cm.) are borne seven to ten *seeds* which vary greatly in size up 1.7 mm. and have fine but distinct reticulations visible under a lens.

MICROSCOPIC STRUCTURE.—Kinzel [1] found this seed to be the only one of the genus grown in India with cellular structure evident in the *outer epiderm*, also that the *palisade layer*, after treatment with acid and alkali, is of a more brown-yellow color than others of the genus. Meshes up to 150 μ are formed by the variation in height of the palisade cells which range up to 20 μ in tangential diameter, the lumen usually being narrower than the double walls. Cross sections show that the radial walls of the palisade cells pass into threads in the outer portion.

CHIEF STRUCTURAL CHARACTERS.—See tables.

DISSECTED MUSTARD

Brassica dissecta Boiss. = *Sinapis dissecta* Lagasca.

This seed is grown for oil in southern Russia and occurs as an impurity in linseed, linseed cake, and rape cake from that region. It is closely related to white mustard and may be merely a brown seeded form of the same species, bearing the same relation to the white form as brown sarson does to white or yellow sarson.

MACROSCOPIC STRUCTURE.—The *seed* closely resembles that of white mustard, the chief difference being that it is dull red-brown and has somewhat more distinct reticulations visible under a lens.

MICROSCOPIC STRUCTURE.—Gram [2] and Burchard [3] give cuts showing the structure and Böhmer [4] reproduces Gram's cuts. Kinzel [5] corroborates Burchard's statements. All appear to agree that the only material difference from white mustard is the presence of brown coloring matter in the thickened portion of the walls of the *palisade layer* and the contents of the *pigment cells*, also the more unequal height of the palisade cells producing a dark network in surface mounts and the reticulations seen on the seed under a lens.

CHIEF STRUCTURAL CHARACTERS.—See tables.

[1] Landw. Vers.-Stat. 1899, **52**, 169.
[2] Ibid. 1898, **50**, 449.
[3] J. Landw. 1894, **42**, 125.
[4] Kraftfuttermittel. Berlin, 1903, p. 426.
[5] Landw. Vers.-Stat. 1899, **52**, 169.

TORI OR BROWN INDIAN RAPE

Brassica Napus L. var. *dichotoma* Prain.

This plant is grown in northern Bengal and adjoining provinces for oil production and to some extent as a leaf vegetable. Cake from the seed is rare in European commerce.

MACROSCOPIC STRUCTURE.—Including the beak (1.5 cm.) the two-valved *pods* vary up to 5.5 cm. in length. The small dark brown *seeds* vary greatly in size. One of Prain's samples marked "Lutni" from the province Chota Nagpur had seeds up to 2.2 mm. in diameter; another marked "Bhunri" up to only 1.8 mm. Both appeared finely granular but not reticulated under a lens.

MICROSCOPIC STRUCTURE.—No cellular structure is evident in the *outer epiderm* and *subepiderm* in cross sections mounted in water, although on heating with sodium hydroxide the cells may be expanded so as to show faint walls. The *palisade cells* are unequal in height, forming a dark network in surface view with meshes up to 125 μ in diameter. The individual palisade cells reach a maximum of 25 μ in diameter. Kinzel [1] states that the lumen, as in common rape, is broad and the wall very thin. It is generally true of the variety Lutni that the lumen is as broad or broader than the double walls, but the reverse is the rule in the variety Bhunri. His statement that the *aleurone layer* of the endosperm is often two cells thick needs qualification. It is true that in some parts of the seed the layer is double, but this is also true of other species.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—An analysis by Werenskiold [2] follows:

Composition of Tori (Werenskiold)

	%
Water	5.74
Protein	21.00
Fat (ether extract)	41.23
N-f. ext.	13.08
Fiber	12.52
Ash	6.43
True protein	18.69
Volatile mustard oil*	0.32
Lecithin†	2.76
Sucrose, gravimetric	0.92
Sucrose, polarimetric	1.23

* Schlicht method. † Schulse and Frankland method.

[1] Landw. Vers.-Stat. 1899, **52**, 169.

[2] Tidskr. norske Landbr. 1895, **2**, 273.

Volatile Mustard Oil.—Kinzel[1] in 2 samples of the variety Lutni found 0.24 and 0.56 per cent of volatile oil and in the variety Bhunri 0.85 per cent.

Fatty Oil.—Crossley and Le Sueur[2] obtained in the oil from seed grown in the northwest provinces of India: specific gravity at 15.5° C. 0.9154, saponification number 172.2, iodine number 104.8, Reichert-Meissl number 0.22, Hehner number 94.6, and acid number 1.57 (equivalent oleic acid 0.79 per cent).

COMMON RAPE

Brassica Napus L. var. *oleifera* D.C.

Fr. Navette. Sp. Colza. It. Colza. Ger. Raps.

It is in the group known as rapes or colzas, that is the species and varieties of *Brassica* cultivated for oil, that the common and scientific nomenclature is most confused. Whether or not it is possible in the case of this genus, as of many others of cultivated plants, to find the wild parents of the numerous forms which have been developed by man, at least a halt should be called in renaming old varieties and adding new without a thorough study of the whole genus. Many of the chemical analyses of "rape oil" are valueless because it is impossible to learn the botanical identity of the seed.

Common rape is extensively grown throughout Europe. There are Summer (sub-variety *annua*) and Winter (sub-variety *hiemalis*) agricultural varieties. In the United States it is practically unknown in agriculture. Rape oil was once a common illuminant and still is burned in altar lamps, lanterns, etc., although its chief use is for purposes such as soap-making where petroleum oils are not applicable.

Because of its non-pungent taste the cake is an excellent cattle food.

MACROSCOPIC STRUCTURE (Fig. 181).—Rape *seed* is larger than any of the pungent brown-seeded mustards, reaching 2.5 mm. Under a lens of low power the surface is dull but not reticulated. With higher magnification very fine reticulations are evident.

MICROSCOPIC STRUCTURE.—Harz,[3] one of the first to study rape seed, obtained results since confirmed by other investigators.

Spermoderm (Fig. 182, *S*; Fig. 183).—Cellular structure is evident in cross section in the third or *palisade layer* (*pal*) and the fourth or *pigment layer* (*pig*), but only in surface view and after careful observa-

[1] Loc. cit.

[2] J. Soc. Chem. Ind. 1898, **17**, 989.

[3] Samenkunde. Berlin, 1885, p. 932.

tion do the *outer epiderm* (*ep*) and *subepiderm* (*sub*) show details of their thin-walled cells.

Characteristic are the uniform height, large size (up to 35 μ), and relatively broad lumens of the *palisade cells*. Because of the even height

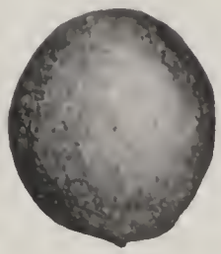


Fig. 181.

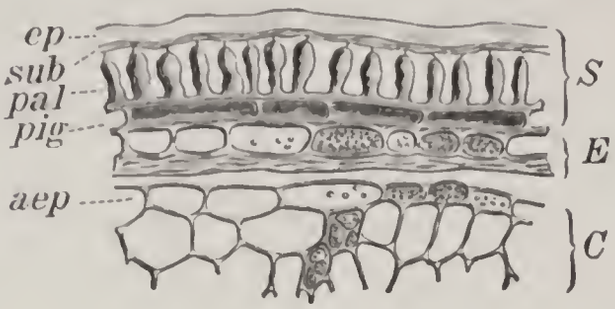


Fig. 182.

Fig. 181.—Common Rape. Seed. ×10. (A.L.W.)

Fig. 182.—Common Rape. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *sub* subepiderm, *pal* palisade cells, *pig* pigment cells. *E* endosperm. *C* cotyledon showing *aep* outer epiderm and mesophyl containing aleurone grains. ×160. (K.B.W.)

of the palisade cells, which Pieters and Charles [1] found do not vary more than 3 μ, reticulations are not evident under the microscope. The breadth of lumen of these cells as seen in surface view equals or exceeds

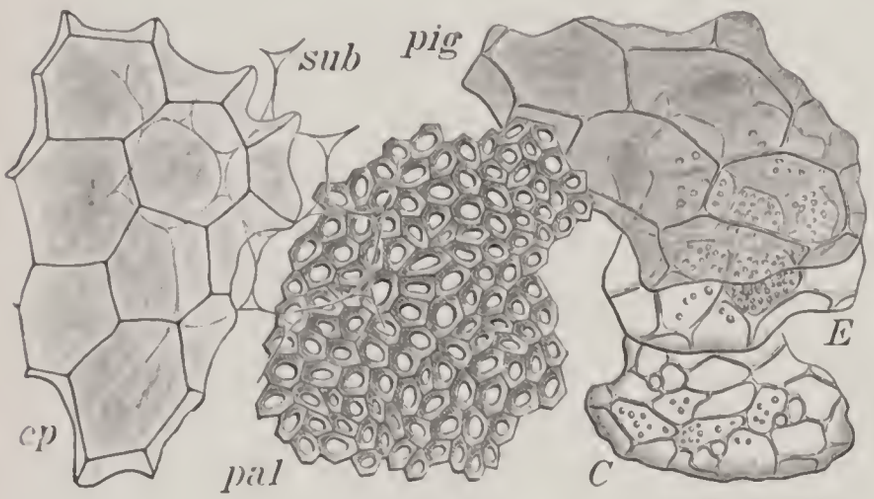


Fig. 183.

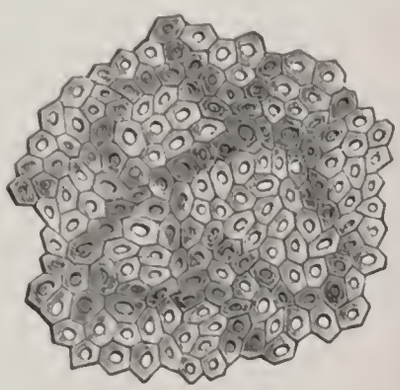


Fig. 184.

Fig. 183.—Common Rape. Seed in surface view. Spermoderm: *ep* outer epiderm, *sub* subepiderm, *pal* palisade cells, *pig* pigment cells. *E* endosperm. *C* outer epiderm of cotyledon. ×160. (K.B.W.)

Fig. 184.—German Rape. Palisade cells in surface view. ×160. (K.B.W.)

that of the double wall. This was first pointed out by Harz, who also found that in German rape (Fig. 184) the lumen is smaller.

Endosperm (Figs. 182 and 183, *E*).—As in black mustard.

Embryo (Fig. 182, *C*; Fig. 183).—The general structure of cotyle-

[1] U. S. Dept. Agr., Div. Bot. 1901, Bul. 29.

dons and radicle is the same as in other members of the genus. *Myrosin cells* are less numerous than in the mustards.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—The composition of rape seed and rape cake attracted the attention of early agricultural chemists because of their high feeding value. Förster [1] states that rape cake was the first residue of the oil-seed industry to be used as a cattle food. At that time the production of the seed in Europe was great owing to the use of the oil as an illuminant.

In the United States the rape-seed industry has never gone beyond the experimental stage and the cake is practically unknown in agriculture.

The summary below is of 22 analyses compiled prior to 1891 by Dietrich and König [2] and was quoted by Förster in 1898 as still valid. The air-dry material has an average water content of 7.3 per cent, but the figures here given are on the water-free basis.

Composition of Water-Free Rape Seed (Dietrich and König)

	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%
Min	15.2	35.7	13.1	4.0	3.2
Max	28.1	56.2	23.9	7.1	9.7
Aver	**21.08**	**48.55**	**19.41**	**6.42**	**4.54**

A comparison of the above results with those for the smaller seed of German rape show that the protein content of rape seed is lower and the oil content higher in accordance with the rule given by Förster.

From the analysis of the seed may readily be calculated the composition of the cake for any given yield of oil. Published analyses are not always consistent with such calculation because of the presence of impurities. By pressing, sometimes half of the oil is left in the cake, whereas by extraction as little as 2 per cent of the total oil may remain.

Proteins.—The chief protein of mustards and rapes appears to be a *globulin*, but our knowledge is limited to brief mention by Weyl.[3]

Volatile Mustard Oil.—Förster [1] in his monograph on rape cake has compiled results on the volatile oil in rape seed and rape cake. In the seed the figures by Dircks, Schuster, Mecke, Ulbricht, and Förster

[1] Landw. Vers.-Stat. 1898, **50**, 371.
[2] Zusam. Verd. Futterm. 1891, **2**, 1316, 1334.
[3] Z. physiol. Chem. 1877, **1**, 72.

show a range of from 0.047 to 0.30 and an average of 0.123 per cent. Since extreme figures were obtained by Förster himself, the variation cannot properly be ascribed to difference of method or manipulation.

In the cake the results by Dircks, Schlicht, Ulbricht, and analysts at the Dahme Station show a range of from 0.036 to 1.08 and an average of 0.351 per cent. The highest percentages in both seed and cake appear to be due to the presence of foreign cruciferous seeds such as black or brown mustard.

More difficult to explain than these high results are the exceedingly low results obtained by Ulbricht and quoted by Förster in 10 samples of rape cake which ranged from 0 to 0.043 and on single samples of the cake of black mustard and Indian mustard which were respectively only 0.14 and 0.032 per cent. Even more remarkable is the fact that the same 10 samples of rape cake on addition of white mustard yielded 0.202 to 0.542 per cent and the black and brown mustards 0.819 and 1.016 per cent respectively. It is a common practice in the mustard trade to mix white mustard with black mustard, thus compensating for a deficiency of myrosin in the latter, but numerous determinations by various analysts, in both rape cake and black mustard cake obviously unmixed with white mustard, quoted elsewhere in Förster's monograph, are strikingly at variance with the infinitesimal amounts found by Ulbricht without addition of white seed.

It is most unfortunate that there is a lack of determinations of volatile oil in rape seed and rape cake proved by botanical analysis to be absolutely pure.

Fatty Oil. *Physical and Chemical Values.*—Since the term rape oil is loosely applied to the product of both true rape and German rape it was found impracticable to prepare separate statements of composition. The following limits apply to both oils:

Values of Rape Oil (Compiled)

	Sp. gr. 15.5° C.	Refractive index 25° C.	Solidifying point	Maumené No.	Saponification No.	Iodine No.	Reichert-Meissl No.	Hehner No.	Fatty acids, titer
			° C.						° C.
Min.....	0.913	1.4706	−12	49	170	93	0.2	94	6
Max.....	0.917	1.4757	−5	65	179	105	0.4	96	18

Effects of Ageing in Sunlight.—Gripper [1] stored samples in closed bottles in sunlight for from 4 to over 10 years. Analyses showed marked

[1] J. Soc. Chem. Ind. 1899, **18**, 342.

but not uniformly progressive changes. The values of the fresh oil and the oil after storage for 8 years and 9 months when the maximum changes were reached were: specific gravity at 15.5° C. 0.9140 and 0.9356, free fatty acids as oleic 2.70 and 13.35 per cent, saponification number 177.8 and 197.2, iodine number 99.08 and 63.89, Reichert-Meissl number — and 20.2, and soluble fatty acids equivalent to percentage of potassium hydroxide 0.39 and 3.48. These profound changes help us to understand some of the unusual values of this and other oils given in the literature.

Composition of Rape Oil.—Determinations of the fatty acids before and after hardening have been made by Sudborough, Watson, Ayyar, and Damle [1] in rape oil and by Sudborough, Watson, Ayyar, and Mirchandani [2] in Jamba oil. Jamba oil is stated to be an inferior oil obtained from a wild Indian rape, the values of which fall within the limits for rape oil given above. The results in percentages of the total acids tabulated below should be compared with those given under Indian mustard:

	Rape Oil		Jamba Oil	
	Original	Hardened	Original	Hardened
	%	%	%	%
Lignoceric acid	2.4	2.4	1.8	1.8
Behenic acid	0.5	57.6	4.5	50.8
Stearic acid	1.6	38.5	4.2	47.4
Myristic acid	1.5	1.5		
Erucic acid	57.2	.....	46.3	
Oleic acid	20.2	.....	28.7	
Linolic acid	14.5	.....	12.4	
Linolenic acid	2.1	.....	2.1	
	100.0	100.0	100.0	100.0

Sterols.—In the ether extract of rape cake Stellwaag [3] found 3.29 per cent of unsaponifiable matter. The sample, however, contained 13.48 per cent of free fatty acids and the oil was not representative. Lewkowitsch considers an oil with over 2 per cent as suspicious.

The sterols, according to Windaus and Welsch,[4] consist of brassicasterol ($C_{28}H_{46}O + H_2O$) melting at 148° C. and a phytosterol resembling sistosterol, melting at 142° C.

[1] J. Ind. Inst. Sci. 1926, **9A**, 26.
[2] Ibid. 52.
[3] Landw. Vers.- Stat. 1890, **37**, 135.
[4] Ber. 1906, **39**, 4378; 1909, **42**, 612.

Carbohydrates.—Determinations by Hellriegel [1] of sugar, tannin, etc., in air-dry Winter rape showed 7.7 per cent and of gums (?) 16.2 per cent. Fleury [2] found in Winter rape 7.23 per cent of sugar, dextrin, and gum, and 7.72 per cent of other nitrogen-free constituents. See Förster's monograph.[3]

Phosphorus-Organic Compounds. *Lecithin.*—Stellwaag [4] found 6.99 per cent of lecithin in the ether extract. Soxhlet (quoted by Förster), however, reported only traces.

Phytin.—See Indian Mustard.

Mineral Constituents.—The following is a summary of 13 analyses of the ash of common rape by Wolff.[5] Analyses of German rape by the same author show a similar composition:

Composition of Rape Seed Ash (Wolff)

	Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Min.....	3.36	21.34	0.00	10.40	6.57	0.63	35.57	0.00	0.00	0.00
Max.....	5.19	29.49	8.23	17.30	15.55	3.32	47.49	9.41	5.99	0.83
Aver.....	**4.44**	**24.50**	**1.63**	**14.18**	**11.80**	**1.56**	**42.33**	**2.39**	**1.42**	**0.16**

* In dry seed.

Minor Mineral Constituents. *Iron.*—Seed 59 mg. per kilo, dry basis (McHargue).[6]

Manganese.—Seed 46 mg. per kilo, dry basis (McHargue).[6]

GERMAN RAPE

Brassica Rapa L. var. *oleifera* D.C.

Fr. Rabette. Ger. Rübsen.

This variety is also known as the turnip rape inasmuch as it doubtless had the same origin as our ruta baga and is classed as a variety of the same species. Like common rape there are Summer (sub-variety *annua*) and Winter (sub-variety *hiemalis*) agricultural varieties. It is grown in various parts of Europe for oil production, and the cake is used in feeding. In the United States a variety known as dwarf Essex rape is cataloged as a cover crop and for Fall forage of sheep and swine.

[1] Chem. Ackersm. 1861, 94.
[2] Ann. chim. phys. 1865 (4), IV, 38.
[3] Loc. cit.
[4] Loc. cit.
[5] Aschenanalysen 1880, p. 160.
[6] J. Agr. Res. 1923, **23**, 395.

MACROSCOPIC STRUCTURE.—Compared with common rape the *seed* is smaller and has evident reticulations.

MICROSCOPIC STRUCTURE.—As was first brought out by Harz,[1] the structure differs from that of common rape chiefly in breadth of lumen of the *palisade cells*. In common rape the lumen is broad (Fig. 183, *pal*), equaling the double walls; in German rape (Fig. 184) it is narrower than the double walls.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—A comparison of the following summary of analyses of German rape seed compiled by Dietrich and König [2] with the corresponding summary of rape seed shows much higher percentages of protein and lower percentages of fat, the differences being in accord with Förster's observation on the relation of size of seed to protein and fat content:

Composition of Water-free German Rape Seed (Dietrich and König)

	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%
Min	12.2	25.4	.....	9.2	3.6
Max	27.6	45.7	.....	10.9	5.1
Aver	**22.2**	**36.4**	**26.5**	**10.8**	**4.1**

No marked differences in composition between rape and German rape, other than those shown in the summary of proximate analyses, have been established. Commercial rape oil may be made from one or the other species, and the range of constants given under rape oil applies to both.

SARSON

Brassica campestris L. var. *Sarson* Prain = *Sinapis glauca* Roxb.

Indian colza, the name sometimes applied to this species, is misleading since there are other Indian rapes or colzas. White, or better yellow, Indian rape is an appropriate name for the yellow-seeded varieties, which are the more common. To avoid confusion it seems best to use the native names for all the Indian rapes.

Yellow-seeded sarson, under various names such as Guzerat rape and yellow Indian rape, has been imported into Europe as an adulterant of white mustard. Viehoever, Clevenger, and Ewing [3] describe a Chinese

[1] Samenkunde. Berlin, 1885, p. 938.

[2] Zusam. Verd. Futterm. 1891, **2**, 1316, 1334.

[3] J. Agr. Res. 1920, **20**, 117.

rape, imported into the United States during the war, that is similar if not identical with sarson.

Sarson cake is well thought of in Europe as a cattle food.

MACROSCOPIC STRUCTURE.—The *pod* has a conical beak less than half its length and is either upright or pendant, the latter being the longer (maximum 8 cm.). Normally it is two-valved and two-celled but it may have in addition one or two false valves. As many as eighty seeds may be present in a pod.

The *seed* in most varieties is yellow, closely resembling white mustard in color, size, and the absence of distinct reticulations. The following are the maximum diameters obtained by the writers in 6 of Prain's samples of yellow sarson from the provinces of Bengal and Bihar: Seti Sarishá 2.4 mm., Piarki Tori 2.8 mm., Piarka Tora 3.0 mm., Jauda Sarson 2.0 mm., Natua Sarson 2.3 mm., Ulti Sarson 2.5 mm. These measurements are in harmony with Kinzel's average weights. Most of the samples contained a few brown seeds. Duthie finds that yellow and brown seeds may occur on the same plant.

One of Prain's samples, Lalka Tora from the province of Bihar, is of a clear brown color, lighter than ordinary brown mustards and rapes. The maximum diameter of the remarkably uniform seeds is 3 mm.

MICROSCOPIC STRUCTURE.—Kinzel [1] has correctly observed that none of the varieties shows cellular structure in the *outer epiderm* and *subepiderm* in cross section. Measured in surface mounts the *palisade cells* vary in diameter up to over 30 μ, the double walls equaling or exceeding the lumen in breadth. Only in Piarki Tori was a network evident and this was indistinct.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—An analysis by Werenskiold [2] follows:

Composition of Sarson (Werenskiold)

	%
Water	5.14
Protein	22.00
Fat (ether extract)	44.44
N-f. ext.	10.05
Fiber	14.74
Ash	3.65
True protein	18.56
Volatile mustard oil*	0.51
Lecithin†	3.75
Sucrose, gravimetric	0.79
Sucrose, polarimetric	0.99

* Schlicht method. † Schulze and Frankland method.

[1] Landw. Vers.-Stat. 1899, **52**, 169. [2] Tidskr. norske Landbr. 1895, **2**, 273.

Volatile Mustard Oil.—Cultivated varieties from different Indian provinces, examined by Kinzel,[1] yielded the following percentages of volatile mustard oil:

	%
Seti Sarishá	0.68
Piarki Tori	0.75
Piarka Tora	0.79
Jauda Sarson	0.64
Makhan Dhaná Sarishá	0.64
Natua Sarson	0.63
Ulti Sarson	0.81–0.88
Lalka Tora	0.56

Ulbricht (quoted by Förster)[2], in 3 samples of press cake from "*B. glauca*," found 0.77, 0.82, and 1.02 per cent of volatile mustard oil.

Fatty Oil.—Crossley and Le Sueur [3] found in oil from seed grown in the northwestern provinces of India: specific gravity at 15.5° C. 0.9142, refractive index at 25° C. (recalculated) 1.4707, polarization in 200-mm. tube −10, saponification number 171.4, iodine number 97.7, Reichert-Meissl number 0.67, Hehner number 95.0, and acid number 1.78 (equivalent oleic acid 0.89 per cent).

CHINESE RAPE

Brassica campestris L. var. *chinensis* Ito = *B. chinensis* L.

This species, according to M. Kondo,[4] to whom we are indebted for our knowledge of the morphology and histology of the seed, is one of the most important cultivated plants of Japan and China. Most of the varieties have been developed as leaf or root vegetables, but *abura-na* is grown for its oleaginous seeds which in former years yielded the then chief lamp oil of Japan.

MACROSCOPIC STRUCTURE.—The *seeds* are grouped according to their form as: (1) globular (*Tschōsen-abura-na, Sankei-abura-na*), (2) ovoid (*Tōkiō-wase-abura-na, Mie-abura-na*), and (3) chestnut-shaped with a short beak (*Hamburg-abura-na*).

All the *abura-na* varieties have moderately distinct, medium large reticulations (58 to 64 μ). Some of the varieties grown as vegetables have very distinct large reticulations (up to 108 μ), others indistinct small

[1] Loc. cit.

[2] Landw. Vers.- Stat. 1898, **50**, 371.

[3] J. Soc. Chem. Ind. 1898, **17**, 989.

[4] Ber. Ohara Inst. landw. Forsch. 1917, **1**, 125.

reticulations (49 μ). The color of the *abura-na* seeds when fully ripe is usually deep black. One thousand of the seed weigh from 2.78 to 3.73 grams, according to the variety. The range in length is from 1.6 to 2.3 mm.

MICROSCOPIC STRUCTURE. **Spermoderm.**—The *epiderm* and *subepiderm* in cross section form thin, apparently structureless bands. This applies to all the varieties examined by Kondo. The *palisade cells* as seen in cross section have lumens about equaling in width the double walls, the latter being impregnated with brown coloring matter. The *pigment layer* consists of collapsed brown cells with thin indistinct membranes.

The **Endosperm** consists of a single layer of *oil cells* and a collapsed thin-walled tissue appearing structureless in cross section.

Because of lack of certain data seeds of this species are not listed with other cruciferous seeds in the tables.

CHEMICAL COMPOSITION.—Because data on the composition of the whole seed are lacking, an analysis of the cake by Yoshimura and Fujise [1] is here given. The cake contained 10.84 per cent of water; the dry matter contained as follows:

Composition of Chinese Rape (Yoshimura and Fujise)

(Dry basis)

Protein	Fat	N-f. ext.*	Ash
%	%	%	%
38.44	13.47	36.46	11.63

* Includes fiber.

Bases.—From a warm water extract of the cake the same authors obtained small amounts of adenine, arginine, choline, and betaine.

Oil.—Values of the authentic oil are not at hand.

Toyama [2] states that about 65 per cent of the oil is erucic acid and less than 2 per cent saturated acids consisting of palmitic acid with probably stearic, behenic, lignoceric, and arachidic acids. Linolenic, linolic, and oleic acids were shown to be present.

Mineral Constituents.—The ash of the cake examined by Yoshimura and Fujise [1] contained (recalculated):

[1] J. Chem. Soc. Japan, 1924, **45**, 42.
[2] J. Chem. Ind. Japan, 1922, **25**, 1044.

Composition of Ash of Chinese Rape Seed Cake (Yoshimura and Fujise)

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2*	Cl	CO_2
%	%	%	%	%	%	%	%	%	%	%
11.61	6.45	5.50	7.14	8.51	trace	22.87	5.76	3.18	0.09	28.89

* Includes sand.

HEDGE MUSTARD

Sisymbrium officinale (L.) Scop. = *Erysimum officinale* L.

Fr. Tortelle. Sp. Erisimo. It. Sisimbro. Ger. Eisenkraut.

Herba Sisymbrii (*S. officinale* Scop.) is officinal in the pharmacopœias of several countries and is a household herb. It is a roadside weed described by Gram [1] because of the possible occurrence of its seed in rape cake, although he expressly states he has not found it there.

MACROSCOPIC STRUCTURE.—The light brown elongated *seeds* with incumbent cotyledons resemble those of false flax in form and coloring but are on a much smaller scale (maximum length 1.3 mm.).

MICROSCOPIC STRUCTURE.—Gram shows the *outer epiderm* with the mucilage in the cells, each with an axial cylinder, or escaped as a cone, the *palisade cells* with thickening only at the inner end, and the *inner parenchyma* with brown contents.

Chief Structural Characters.—See tables.

TUMBLING MUSTARD

Sisymbrium altissimum L.

This weed is one of the worst in Minnesota and North Dakota, having been introduced from neighboring provinces of Canada. Dewey [2] states that it is disseminated in grass seed and hay.

Authentic seed from Minnesota was secured through the courtesy of Prof. W. L. Oswald.

MACROSCOPIC STRUCTURE.—Similar to those of hedge mustard, the yellow-brown *seeds* vary up to 1.3 mm. long and are more or less truncated.

MICROSCOPIC STRUCTURE.—Microscopically the seed from Minnesota conforms closely to Gram's description of hedge mustard

[1] Landw. Vers.-Stat. 1898, **50**, 449.

[2] U. S. Dept. Agr. Div. Bot. 1896, Circ. **7**.

from Europe. Each *outer epidermal cell* has mucilage about a central column which often bursts from the cell as a short cone. The *palisade cells* in cross section show little thickening, even at the inner end where the wall is brown. In surface view they appear thin-walled, the maximum diameter reaching 30 μ.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—No proximate analyses of either hedge or tumbling mustard are available, but Ivanov and Troitzkii [1] obtained the following figures on the physical and chemical values of the oil from the seeds of two other species grown in middle Russia:

	Oil in seed	Saponification No.	Iodine No.	Acid No.
	%			
Sisymbrium laselli L.	33.0	183.29	141.3	1.34
Sisymbrium Sophia L.	28.7	.....	142.4	3.10

HARE'S EAR

Erysimum orientale R. Br. = *Conringia orientalis* (L.) Dumort.

Ger. Schottendotter.

Treacle mustard or hare's ear is quite widely distributed. Beal [2] reports its occurrence in Michigan and Selby [3] in Ohio. The writers have found seeds in screenings from the northwestern hard wheat district of the United States. Gram [4] states that he has detected the seed in Indian and European rape cake.

MACROSCOPIC STRUCTURE.—The elongated *pods* are four-sided and the valves are keeled. The *seeds* (Fig. 185) with incumbent cotyledons are dark brown, irregularly ellipsoidal, up to 2.8 mm. long and about half as broad, and indistinctly striate, the striations sometimes obscured by transverse wrinkles. The spermoderm conforms to the shape of the embryo.

MICROSCOPIC STRUCTURE.—Gram [4] shows the seed in cross section and surface view. Our results corrobate his.

Spermoderm (Fig. 186, *S*).—Only three layers are visible: (1) *outer epiderm* (*ep*) of broad (up to 80 μ) but low cells, with large, radially

[1] Masloboino Zhirovoe Delo. 1928, **1**, 30.

[2] Michigan Agr. Exp. Sta. 1910, Bul. **260.**

[3] Ohio Agr. Exp. Sta. 1906, Bul. **175,** 330.

[4] Landw. Vers.-Stat. 1898, **50,** 449.

elongated pores in the radial walls, containing mucilage which often bursts from the cells forming blunt-tipped or capitate cones, (2) dark brown *palisade cells* (*pal*), up to 55 μ, with strongly thickened inner walls and thin, much elongated radial walls, and (3) *pigment cells* (*pig*) with walls of a brown color.

The elongated pores in the radial walls of the *outer epiderm* are very characteristic. As seen in cross section the walls are fence-like, the pores extending practically from outer to inner tangential walls. In surface view instead of having the typical beaded appearance of a porous

FIG. 185.

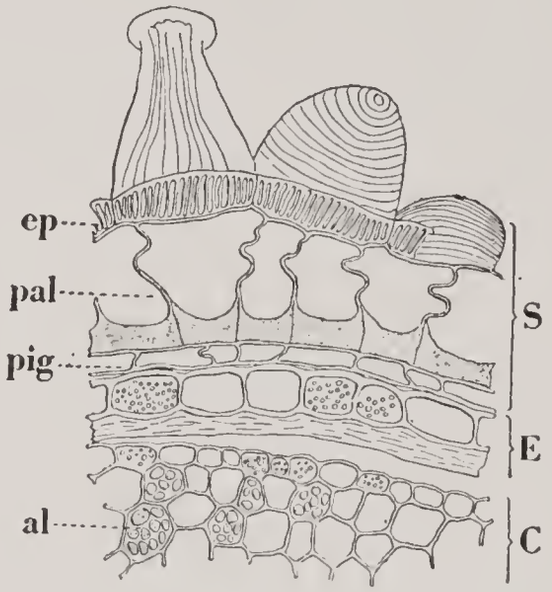


FIG. 186.

FIG. 185.—Hare's Ear. Seed. ×10. (A.L.W.)

FIG. 186.—Hare's Ear. Seed in cross section. *S* spermoderm: *ep* outer epiderm showing escaping mucilage, *pal* palisade cells, *pig* pigment cells. *E* endosperm. *C* cotyledon showing *al* aleurone grains. ×160. (K.B.W.)

wall they are toothed or feathery, owing to the large size of the pores and the thinness of the partitions.

Endosperm (Fig. 186, *E*) and **Embryo** (*C*), as in other cruciferous seeds.

CHIEF STRUCTURAL CHARACTERS.—See tables.

WINTER CRESS

Barbarea vulgaris R. Br. = *B. Barbarea* (L.) MacM. = *Erysimum Barbarea* L.

Fr. Cresson de terre. Ger. Winterkresse.

Under the name of upland or winter cress, seeds of this species are sold by American seedsmen as a salad plant or pot herb. Vasey [1] states

[1] U. S. Dept. Agr. Rep. Bot. 1886, p. 92.

that its occurrence as a weed in the vicinity of the large cities is due to its escape from the gardens. In Europe it is a common weed as well as a vegetable, and Gram [1] reports its occurrence in rape cake. Selby [2] notes that the seed is disseminated in grain as well as in clover and grass seed.

MACROSCOPIC STRUCTURE.—The conspicuous yellow *flowers* are followed by slender, short-beaked, four-sided *pods* up to 3 cm. long containing the irregularly ellipsoidal, somewhat flattened, dull, light brown *seeds* up to 1.2 mm. long with accumbent *cotyledons*.

MICROSCOPIC STRUCTURE.—As drawn by Gram [1] the spermoderm layers are: (1) *outer epiderm* with mucilage only on the inner surface of the outer walls, (2) *subepiderm* of large, often brown and somewhat thickened cells, (3) large *palisade cells* with lumen several times the breadth of the double walls, and (4) *inner parenchyma* with brown contents.

Each *palisade cell* contains a well-formed crystal of calcium oxalate.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—No record has been found of chemical analyses of the seed of winter cress or its products.

The physical and chemical values of the oil obtained by ether extraction from the seed of the salad plant, known in the southern United States as scurvy grass (*Barbarea præcox* R. Br.), as found by Grimme,[3] follow: specific gravity at 15° C. 0.9214, refractive index at 25° C. (recalculated) 1.4732, solidifying point −7 to −5° C., saponification number 180.0, iodine number 137.3, ester number 168.3, fatty acids 94.42 per cent, acid number 11.7 (equivalent oleic acid 5.85 per cent), and solidifying point of fatty acids 21 to 22° C.

FALSE FLAX

Camelina sativa Crntz. = *Myagrum sativum* L. = *Alyssum sativum* Scop. = *Mœnchia sativa* Roth.

Fr. Caméline. It. Cameline. Ger. Leindotter.

Other names for this seed are German sesame and dodder (not the parasite). For some hundreds of years the plant has been grown in central Europe but now is an unimportant crop and the plant figures chiefly as a weed, the seeds of which contaminate flaxseed, rape, and other oil seeds.

[1] Landw. Vers.-Stat. 1898, **50**, 449.
[2] Ohio Agr. Exp. Sta. 1906, Bul. **175**, 330.
[3] Chem. Rev. Fett-Harz-Ind. 1912, **19**, 102.

The cold pressed oil from Russian seed is sometimes used as food; the chief use, however, is for technical purposes.

MACROSCOPIC STRUCTURE.—Small yellow *flowers* and large but short, pointed, margined, many-seeded *pods* characterize this species. The smooth *seed* (Fig. 187) is distinguished at a glance from mustards and rapes by its light brown color,

Fig. 187.

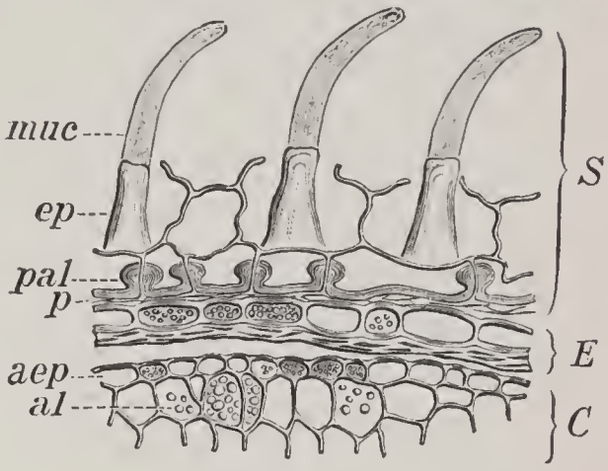


Fig. 188.

Fig. 187.—False Flax. Seed. ×10. (A.L.W.)

Fig. 188.—False Flax. Seed in cross section. *S* spermoderm: *ep* outer epiderm showing *muc* escaping mucilage, *pal* palisade cells, *p* parenchyma. *E* endosperm. *C* cotyledon showing *aep* outer epiderm and mesophyl containing *al* aleurone grains. ×160. (K.B.W.)

elongation (up to 2.3 mm.), and the form of the embryo with its incumbent *cotyledons* to which the spermoderm conforms.

MICROSCOPIC STRUCTURE.—Descriptions of this seed are given by several authors, who have studied cruciferous seeds, beginning with Harz.[1] Nevinny [2] and Van Pesch [3] have published special articles.

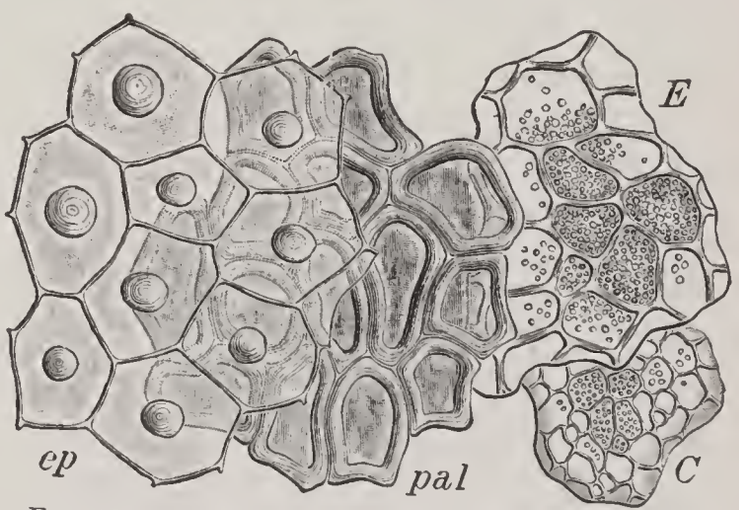


Fig. 189.—False Flax. Elements of seed in surface view. Spermoderm: *ep* outer epiderm, *pal* palisade cells. *E* endosperm. *C* outer epiderm of coyledon. ×160. (K.B.W.)

Spermoderm (Fig. 188, *S*; Fig. 189).—Only three layers are evident: (1) large *outer epidermal cells* (*ep*) from which mucilage (*muc*) escapes in water as finger-like cylinders, (2) *palisade cells* (*pal*), broad (up to nearly 100 μ) but low, with lumen often several times the breadth of the thickened brown radial walls, and (3) *compressed parenchyma* (*p*).

[1] Samenkunde. Berlin. 1885, p. 923. See references in preliminary chapter.
[2] Z. Nahr.-Unters. Hyg. 1887, **1**, 85.
[3] Landw. Vers.-Stat. 1892, **41**, 94.

Highly characteristic in surface view are the tapering columns of *mucilage*, each at the base forming a circle in the middle of an outer epidermal cell, and the large light brown *palisade cells*, several times the diameter of the largest palisade cells of any mustard or rape, with thick, double walls reaching 20 μ and lumens 70 μ.

Endosperm (Figs. 188 and 189, *E*).—A single layer of aleurone cells like those of species of *Brassica*.

Embryo (Figs. 188 and 189, *C*).—The structure of the embryo is like that of species of *Brassica* but the *aleurone grains* (*al*) are smaller.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—The composition of the seed and cake as compiled by Harz [1] follows:

Composition of False Flax (Harz)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Seed:						
Min.....	7.5	18.6	29.4	17.3	10.7	4.5
Max.....	10.0	25.9	31.8	35.1	11.5	9.2
Cake:						
Min.....	9.7	28.5	8.1	.....	10.7	6.0
Max.....	15.0	36.5	10.3	.....	12.5	7.2
Aver.....	**11.8**	**33.1**	**9.2**	**27.6**	**11.6**	**6.7**

Fatty Oil.—Grimme [2] reports the following physical and chemical values: specific gravity at 15° C. 0.9224, refractive index at 25° C. (recalculated) 1.4743, solidifying point −16 to −15° C., saponification number 185.8, iodine number 135.1, ester number 172.6, fatty acids 94.1 per cent, acid number 13.2 (equivalent oleic acid 6.64 per cent), and solidifying point of fatty acids 15 to 16° C.

SHEPHERD'S PURSE

Capsella Bursa-pastoris Mœnch.

Sp. Bolsa de pastor. It. Borsa da pastore. Ger. Hirtentäschel.

Being one of the commonest of weeds in Europe, where it is indigenous, and in the United States, where it has been introduced, the seed is of frequent occurrence notably in rape, linseed, and other oil seeds.

[1] Samenkunde. Berlin, 1885, p. 925.

[2] Chem. Rev. Fett-Harz-Ind. 1912, **19**, 102.

MACROSCOPIC STRUCTURE.—Although the small white *flowers* are terminal, on ripening, the *pods* form a much elongated raceme resembling a bottle brush. Each pod varies up to 7 mm. in length. Being flattened and notched at the end, it is purse- or inverted heart-shaped. The two boat-shaped valves separate from the partition releasing numerous minute medium brown or yellow seeds. The shape of the *seeds* is much like that of false flax but is much smaller, the largest being only 1.3 mm. long. The *cotyledons* are incumbent.

MICROSCOPIC STRUCTURE.—Gram [1] shows the spermoderm and endosperm in cross section and surface view.

Spermoderm (Fig. 190, *S*; Fig. 191).—Three layers are evident: (1) *outer epidermal cells* (*ep*) containing mucilage about a central column, (2) yellow-brown *palisade cells* (*pal*) which are broad (up to 60 μ) with lumens several times the breadth of the double walls, but very low, and (3) *parenchyma*, consisting of a single layer of very broad cells over the flat surface of the seed and several cell layers of smaller cells over the edges.

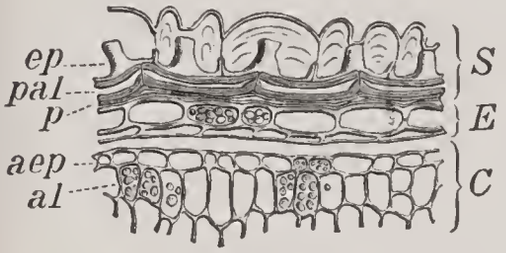


Fig. 190.

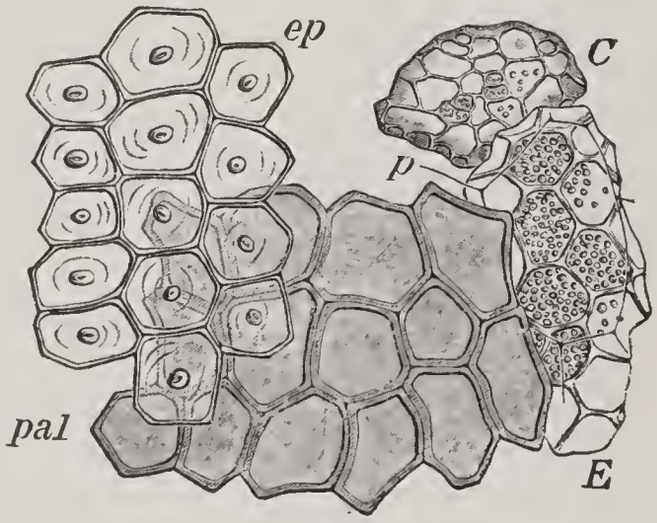


Fig. 191.

Fig. 190.—Shepherd's Purse. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *pal* palisade cells, *p* parenchyma. *E* endosperm. *C* cotyledon: *aep* outer epiderm, *al* aleurone grains. ×160. (K.B.W.)

Fig. 191.—Shepherd's Purse. Elements of seed in surface view. Reference letters as in Fig. 190. ×160. (K.B.W.)

The *outer epidermal cells*, arranged in longitudinal rows as seen in surface view, show a somewhat thickened primary wall and a zone of non-mucilage tissue about the small central lumen; between these is a mass of mucilage which on addition of water to alcohol mounts slowly distends the outer wall and finally, as in peppergrass, escapes although not so quickly and without forming extra-cellular, finger-like bodies as in false flax.

Endosperm and Embryo (Figs. 190 and 191, *E*, *C*).—As in allied species.

Chief Structural Characters.—See tables.

[1] Landw. Vers.-Stat. 1898, **50**, 449.

WILD PEPPERGRASS

Lepidium virginicum L.

Fr. Cresson. Sp. Lepidio. It. Crescione. Ger. Kresse.

This common weed, although according to Gray native of the South, grows everywhere in the United States. It occurs in grain and flaxseed.

In certain sections European species, notably *L. apetalum* Willd. and *L. campestre* (L.) Br., have gained a foothold, and even *L. sativum* L., our garden cress, has escaped from cultivation. *L. apetalum* is very common in Minnesota and neighboring states and is the only *Lepidium* in the first set of twenty-four Minnesota weed seeds distributed by the Minnesota Experiment Station. According to Gram,[1] *L. campestre* occurs in European rape although he only reports one instance.

MACROSCOPIC STRUCTURE.—As in shepherd's purse, the *flowers* are white and in terminal racemes, the *pods* are flattened at right angles to the partitions and the seeds are yellow-brown. The pods however, are round, the *seeds* occur singly in the cells and are longer (up to 1.8 mm.), much broader and more pointed at one end than are those of shepherd's purse. Furthermore the *cotyledons* are accumbent, being an exception in the genus. In *L. apetalum* the seeds are similar in size but the cotyledons are incumbent.

MICROSCOPIC STRUCTURE.—Seeds of *L. Virginicum* and *L. apetalum* agree so closely in histological structure that the following description based on our own work applies to both and also in a general way to *L. sativum.* Gram[1] figures the palisade cells of *L. campestre* as being about four times as high as broad with radial walls thickened throughout, but lacking a sample of this seed we are unable to check this remarkable difference from the other species.

Spermoderm (Fig. 192, *S*; Fig. 193).—Three layers are seen in cross section: (1) radially elongated *outer epidermal cells* (*ep*) with central mucilage columns bordered and broadened at the outer ends, (2) yellow-brown *palisade cells* (*pal*), up to 40 μ in tangential diameter, with thickened inner ends of radial walls and lumen several times broader than the double walls, and (3) single layer of very thin, colorless, empty *parenchyma* (*p*).

Conspicuous both in cross section and in surface view are the *outer epidermal cells*, the mucilage after escaping not forming a finger-like column as in false flax but disappearing as in shepherd's purse although more quickly. In mature seeds the cells show a very thin primary wall

[1] Landw. Vers.-Stat. 1898, **50**, 449.

and a thickened shrunken zone about the lumen; between the two is a mass of mucilage which escapes so rapidly on the addition of water that it can be seen only with the quickest manipulation. In immature seeds the lumen is packed with *starch grains* which on ripening disappear and the inner cell wall shrivels, forming the characteristic column.

Endosperm (Figs. 192 and 193, *E*) and **Embryo** (*C*) are of the cruciferous type with aleurone grains (*al*) up to 6 μ in diameter.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—No record has been found of chemical analyses of the seed of wild peppergrass.

The *Physical and Chemical Values* of the oil obtained by ether extraction from the seeds of the garden cress (*L. sativum*), as found by

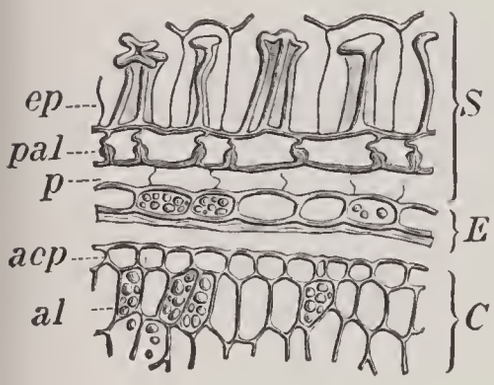


Fig. 192.

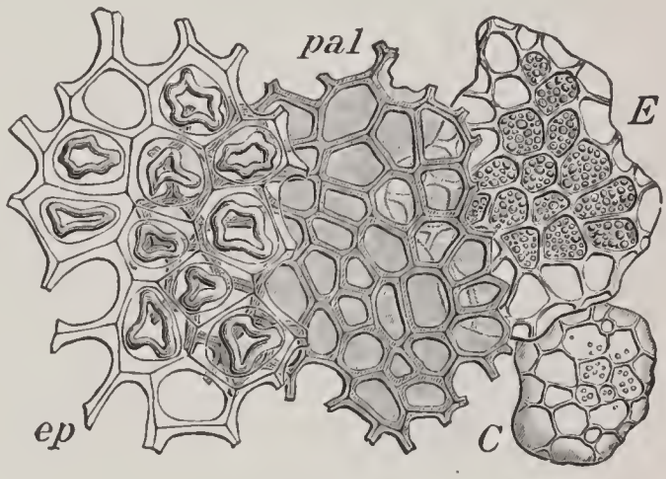


Fig. 193.

Fig. 192.—Wild Peppergrass. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *pal* palisade cells, *p* parenchyma. *E* endosperm. *C* cotyledon: *aep* outer epiderm, *al* aleurone grains. ×160. (K.B.W.)

Fig. 193.—Wild Peppergrass. Elements of seed in surface view. Reference letters as in Fig. 192. ×160. (K.B.W.)

Grimme,[1] follow: specific gravity at 15° C. 0.9238, refractive index at 25° C. (recalculated) 1.4700, solidifying point −16 to −15° C., saponification number 183.7, iodine number 133.5, ester number 171.4, fatty acids 94.08 per cent, acid number 8.3 (equivalent oleic acid 4.18 per cent), and solidifying point of fatty acids 22 to 23° C.

FIELD PENNYCRESS

Thlaspi arvense L.

Ger. Täschelkraut.

French weed has come to be the common name for this plant in the Red River Valley and adjoining regions of Minnesota and North and

[1] Chem. Rev. Fett-Harz-Ind. 1912, **19**, 102.

South Dakota, where it is a most noxious weed. A sample of the seed is included in the first twenty-four of Oswald's collection of Minnesota weeds. It occurs also in Ohio and is given by Cox among the fifty worst weeds of the United States.

In Europe, whence it was introduced into the United States, it does not appear to be so troublesome—at least it is given scant attention by microscopists there. Vogl [1] in the examination of five samples of screenings found it only in one and there only 0.03 per cent. Gram,[2] however, reports finding it in rape cake.

MACROSCOPIC STRUCTURE.—Like its near relative shepherd's purse, the small white *flowers* in a terminal raceme give place on ripening to flattened, inverted heart-shaped pods in a spreading raceme. The *pods* in this species, however, measure up to 1.5 cm., are only several

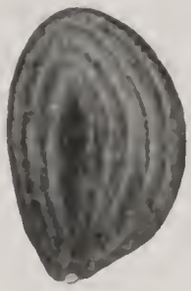


Fig. 194.

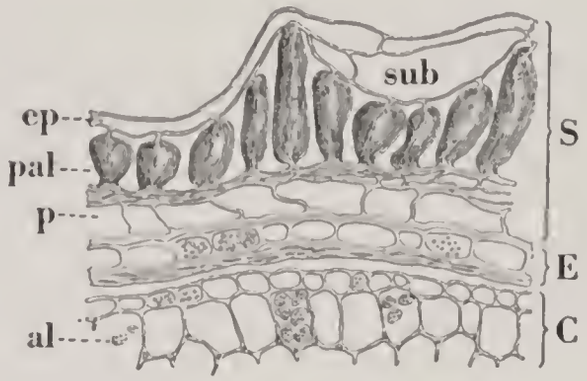


Fig. 195.

Fig. 194.—Field Pennycress. Seed. ×10. (A.L.W.)

Fig. 195.—Field Pennycress. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *sub* subepiderm, *pal* palisade cells, *p* parenchyma. *E* endosperm. *C* cotyledon showing outer epiderm and mesophyl containing *al* aleurone grains. ×160. (K.B.W.)

seeded, and the *cotyledons* are accumbent. The *seed* (Fig. 194) is ellipsoidal, up to 2 mm. long, flattened, dark brown, and shows under a lens the form of the embryo and longitudinal striations instead of reticulations.

MICROSCOPIC STRUCTURE.—Gram [2] illustrates the seed in cross section both mature and immature. Böhmer [3] shows the tissues in surface view.

Spermoderm (Fig. 195, *S*).—All four layers are present although the outer two are more or less obliterated: (1) *outer epiderm* (*ep*) of compressed cells, (2) *subepiderm* (*sub*), also for the most part of com-

[1] Wicht. Nahrungs- u. Genussm. Berlin, 1899, p. 22.

[2] Landw. Vers.-Stat. 1898, **50**, 449.

[3] Kraftfuttermittel. Berlin, 1903, p. 426.

pressed cells, (3) dark brown *palisade cells* (*pal*) varying greatly in height with only the radial walls perceptibly thickened, and (4) *parenchyma* (*p*) with dark walls, the innermost layer showing well expanded cells.

Corresponding with the ridges, the *palisade cells* are twice as high as those midway between. In surface view these higher cells appear darker, forming the dark bands which in the seed take the place of the dark network of species of *Brassica*. The coloring matter is often more intense in the outer thickened portion of the radial walls, which are constricted at both outer and inner end. The tangential diameter of the cells reaches 55 μ, the double walls being much broader than the lumen.

The pigmentation of the *inner parenchyma*, as in the palisade cells, is confined to the cell walls.

Endosperm (Fig. 195, *E*) **and Embryo** (*C*).—Much as in other crucifers with *aleurone grains* (*al*) up to 10 μ.

Chief Structural Characters.—See tables.

CHEMICAL COMPOSITION.—No proximate analysis is available but Ivanov and Troitzkii [1] obtained from seed grown in middle-eastern Russia 37.5 per cent of oil with the following values: saponification number 170.45, iodine number 95.14, and acid number 3.03.

[1] Masloboino Zhirovoe Delo. 1928, No. 1, p. 30.

SEEDS OF THE ROSE FAMILY

(*Rosaseæ*)

The general characters of the family are given in the section headed Fruits of the Rose Family in Volume II. The seeds of two sub-families are here described: (1) *Roseæ*, represented by wild roses, which are a pest in grain fields, and (2) *Pruneæ*, represented by the common drupes, namely almond, peach, nectarine, apricot, plum, and cherry.

ROSE HIPS

Rosa spp.

Fr. Cynorrhodons. It. Bacca della rosa. Ger. Hagebutten.

In Minnesota and adjoining regions the hips or the seed-like achenes of one or more species of rose contaminate the threshed grain. Oswald [1] in his report of the Minnesota Seed Laboratory for 1910–11 states that of 218 samples of seed wheat 9 per cent and of 193 samples of seed oats 6.2 per cent contained rose fruit. Selby [2] states "The seeds of a western species, together with the globular rose-hips containing them, are frequent in western oats."

In Europe the hips of the wild rose (*R. canina* L.) are preserved in syrup and also dried for use as a coffee substitute.

MACROSCOPIC STRUCTURE.—Among the characters of the *flower* shared by numerous species of the genus are the urn-shaped receptacle, narrowed at the throat, where the five green, pointed sepals, five showy petals, and numerous stamens are borne on a disk and the numerous small, hairy pistils, each with a one-celled ovary containing a single anatropous ovule, borne on the inner surface of the receptacle.

Authorities differ as to whether the wall of the *hip* is receptacle or calyx tube. It is here considered to be receptacle. The green pointed calyx lobes that crown the hip dry up during ripening and drop off, leaving a short recurved rim about the opening (Fig. 196, I, II).

A number of buff or brown, more or less pointed, angular *achenes* (II, III), ranging up to about 5 mm. long, are borne on the inner surface

[1] Minnesota Agr. Exp. Sta. 1912, Bul. **127**, 144.

[2] Ohio Agr. Exp. Sta. 1906, Bul. **175**, 334.

of the receptacle in a mass of hairs springing partly from the inner surface of the receptacle and partly from the mature and abortive achenes and the styles. Some of the hairs, as well as the hairy styles, project through the opening at the top of the hip.

Cross sections of the achenes (IV) show that the thick pericarp (*F*) and the thin spermoderm (*S*), perisperm (*N*), and endosperm (*E*) closely invest the seed. The cotyledons (*C*) are elongated, bulky; the radicle is minute at the apex of the fruit.

MICROSCOPIC STRUCTURE.—Several German writers on the structure of foods refer briefly to the so-called "Hagebutten," which are the hips of *Rosa canina*, but without describing the structure in detail.

Receptacle.—The conspicuous elements are the *outer epiderm* consisting of cells shaped like aleurone cells, 80

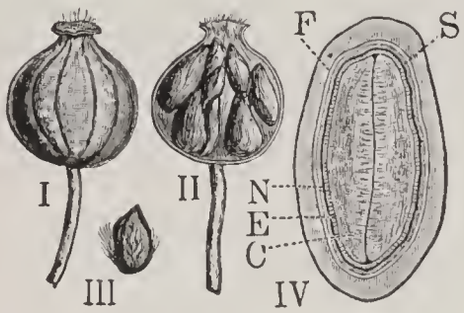


Fig. 196.

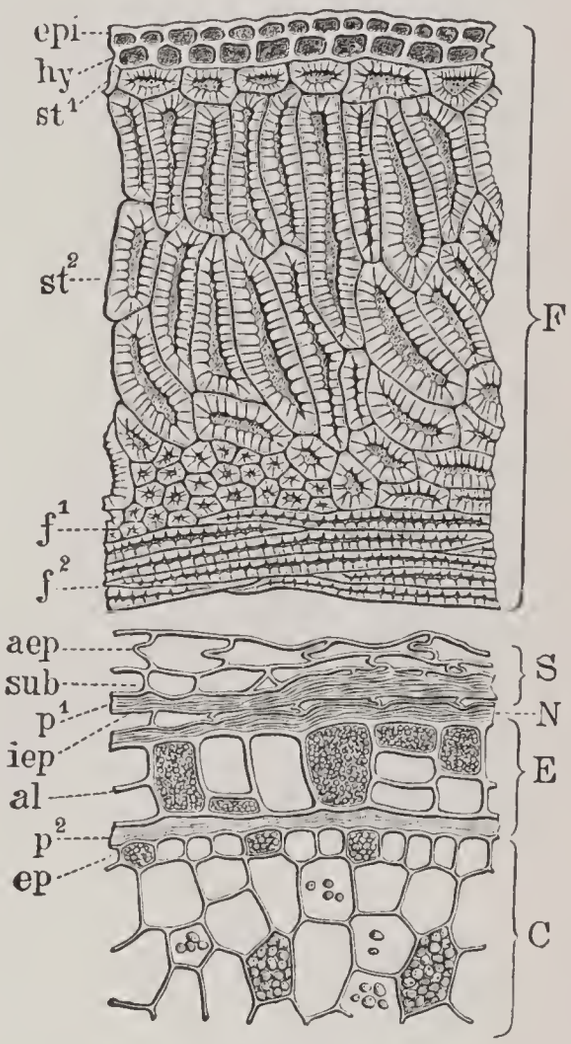


Fig. 197.

Fig. 196.—Rose. I Hip entire; II hip in section; III single achene. ×1. IV Achene in cross section: *F* pericarp, *S* spermoderm, *N* perisperm, *E* endosperm, *C* cotyledons. ×8. (A.L.W.)

Fig. 197.—Rose. Achene in cross section. *F* pericarp: *epi* epicarp, *hy* hypoderm, st^1 tangentially elongated stone cells, st^2 radially elongated stone cells, f^1 longitudinal fibers, f^2 transverse fibers. *S* spermoderm: *aep* outer epiderm, *sub* subepiderm, p^1 compressed parenchyma, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, p^2 compressed parenchyma. *C* cotyledon with *ep* outer epiderm. ×160. (A.L.W.)

to 160 μ in diameter, with walls about 5 μ thick, the crystal clusters in the *mesophyl*, and the numerous hairs on the *inner epiderm* like those of the pericarp.

Pericarp (Fig. 197, *F*; Fig. 198).—Six distinct layers are present, the fifth being interrupted: (1) *epicarp* (*epi*) of cells, mostly elongated, with dark contents, stomata, and thick-walled hairs (t^1, t^2), up to several

millimeters long, (2) *hypoderm* (*hy*) of longitudinally elongated cells with somewhat thickened porous walls, (3) isodiametric or somewhat elongated *stone cells* (st^1), (4) radially *elongated stone cells* (st^2), (5) groups of *longitudinal sclerenchyma fibers* (f^1), and (6) *transverse sclerenchyma fibers* (f^2) forming the endocarp.

The third and fourth layers, made up of stone cells, and perhaps the fifth, made up of sclerenchyma fibers, may be regarded as analogous to the thin-walled pulp cells of other rosaceous fruits.

Breaking through the fibers of the endocarp here and there, especially at the angles, are radially arranged fibers.

Spermoderm (Fig. 197, *S*; Fig. 199).—Four layers, all but the third with yellow walls, may be identified in cross section and surface mounts,

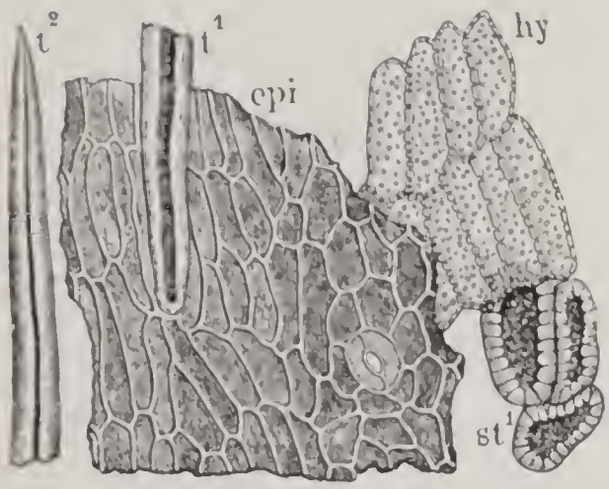


Fig. 198.

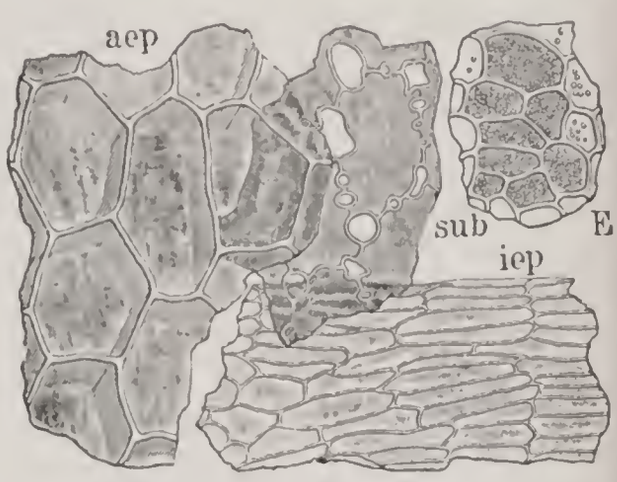


Fig. 199.

Fig. 198.—Rose. Elements of pericarp in surface view. *epi* epicarp; t^1 base, t^2 apex of hair 2 mm. long; *hy* hypoderm; st^1 stone cells of outer layer. ×160. (A.L.W.)

Fig. 199.—Rose. Elements of seed in surface view. Spermoderm: *aep* outer epiderm, *sub* subepiderm, *iep* inner epiderm. *E* aleurone cells of endosperm. ×160. (A.L.W.)

best after treatment with Javelle water to expand the collapsed cells: (1) *outer epiderm* (*aep*) of polygonal cells, often collapsed, hence showing double outline in surface view, (2) *subepiderm* (*sub*) of spongy parenchyma, (3) *compressed parenchyma* (p^1), and (4) *inner epiderm* (*iep*) of transversely elongated, thin-walled cells, often side by side in groups.

The **Perisperm** (Fig. 197, *N*), as in the cereals, consists of a single compressed layer with colorless walls.

The **Endosperm** (Figs. 197 and 199, *E*) consists of (1) a layer of *aleurone cells* (*al*) varying from one to three cells thick, containing aleurone grains about 3 μ in diameter, and (2) *compressed cells* (p^2).

Embryo.—The *cotyledons* (Fig. 197, *C*) contain in addition to fat, oval or polygonal aleurone grains, up to 3 μ in the epiderm and up to

8 μ in the inner cells. Polygonal forms are due to close packing in the cells. Each grain contains several globoids.

CHIEF STRUCTURAL CHARACTERS.—Receptacle hollow, hairy within; achenes borne on inner surface, angular, pointed, hairy, 5 mm. long; pericarp bony. Seed solitary; spermoderm, perisperm, and endosperm thin, closely investing embryo; cotyledons bulky; radicle minute.

Receptacle and epicarp hairs long, straight, thick-walled; epicarp cells elongated; hypoderm cells somewhat thickened, porous; remainder of pericarp largely stone cells and sclerenchyma fibers variously arranged. Spermoderm with large polygonal outer epidermal cells and transversely elongated inner epidermal cells. Perisperm structureless. Endosperm and cotyledons with aleurone grains up to 8 μ.

DRUPES

(*Prunæ*)

With the exception of the almond the drupes have fleshy pericarps which are described under Fruits, Volume II, but the seeds (kernels) of all have a rich store of fat and protein and for that reason are classed in this volume with oily nuts.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *seed* (kernel) is strongly elongated (Jordan almond, most plums), somewhat longer than broad (most almonds, peach) or as broad as long (apricot), and more or less pointed. It has a rough brown skin forming the spermoderm and an inner white skin consisting of perisperm and endosperm. From the hilum, situated near the pointed end, the raphe extends to the chalaza at the broad end where it divides into branches which extend in different directions. The cotyledons are large, white; the radicle is small, in the pointed end.

COMPARATIVE MICROSCOPIC STRUCTURE. Spermoderm.—All the species agree in having four layers: (1) *outer epiderm* of thin-walled, polygonal parenchyma cells interspersed with elevated sclerenchyma cells, (2) *subepiderm* forming a double or triple layer of polygonal cells, without intercellular spaces, which are thin-walled and characterless in all the species but the cherries where some of them are sclerenchymatized and porous, (3) *spongy parenchyma* through which ramify the fibro-vascular bundles, and (4) *inner epiderm* of small cells with brown contents.

Except for the presence of sclerenchyma cells in the subepiderm of the cherry, all the species agree closely in the structure of the second, third, and fourth layers.

The *sclerenchyma cells* of the outer epiderm of all the species but the cherries have been investigated by Wittmack and Buchwald,[1] Hannig,[2] and Young [3] with special reference to the detection of kernels of the fruit stones when substituted for almonds, whether whole or in pastes. The work of these authors was reviewed in the second edition of the

[1] B. deut. bot. Ges. 1901, **19**, 584.
[2] Z. Unters. Nahr.-Genussm. 1911, **21**, 577.
[3] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160**.

"Microscopy of Vegetable Foods" and other distinctions added. Following are the characters of diagnostic value:

(1) Size: large in almond, peach, and nectarine; small in plum and apricot.
(2) Shape of outer wall: truncated in almond; conical in peach, nectarine and plum.
(3) Thickness of outer wall: thin in almond and apricot; thick in peach, nectarine, and plum.
(4) Pores in outer wall: absent in almond and peach· present in nectarine, plum, and apricot.
(5) Chains of small cells: marked in peach; not marked in almond, plum, apricot, and nectarine.

The sclerenchyma cells of the cherries are not included in the above scheme since the kernels, because of their small size, are not suitable substitutes for almonds.

Perisperm.—This, as seen in cross section, forms a band of *compressed cells.*

Endosperm.—Attached to the perisperm, forming a thin white skin, are one or more rows of *aleurone cells* and an inner band of *compressed cells.*

The *aleurone cells* in the different species vary as to the thickness of the layer, measured in number of cells. In the almond and apricot the layer is mostly only one cell thick, in the peach one to three cells, whereas in the plum it runs from one or two on the edges to as high as twenty on the face of the seed.

Embryo.—*Aleurone grains* and *fat* are the visible cell contents of the tissues throughout. Except in the epiderm, where all the grains are small, each cell usually contains one large aleurone grain and numerous small ones. A crystalloid and oxalate rosette are usually seen in each large grain; several globoids in the smaller grains.

COMPARATIVE CHEMICAL COMPOSITION.—The protein in the dry matter ranges from about 18 per cent in the almond to over 35 per cent in the cherry, the fat from about 37 per cent in the cherry to over 60 per cent in the almond. The ratios of protein to fat, calculated from data given under the individual seeds, follow:

Almond	Peach	Apricot	Plum	Cherry
1 : 2.61	1 : 1.75	1 : 1.75	1 : 1.57	1 : 1.38

The arrangement is in the order of the ratios, which is also the order of the size of the kernels, beginning with the largest. These figures, also the minimum and maximum figures given above, are consistent with Förster's rule discussed under Rape, namely, the larger the seed the higher the fat and the lower the protein. This rule, although first

applied to seeds of the same species, appears to hold good, in certain instances at least, for seeds of related species of the same genus.

Proteins.—The chief protein of the almond and the peach is amandin, a globulin. Quite probably other seeds of the group contain the same or a similar globulin.

Fixed Oil.—Judging from the iodine number, the almond, peach, and plum oils are not distinguishable, all falling within the range of 91 to 110. Cherry oil has a higher iodine number, the range being 110 to 123. The percentages of oleic and linolic acid in almond oil are given as 77 and 20 per cent, of apricot oil as 79 and 19 per cent. No figures on the composition of the other oils are at hand.

Glucosides.—*Amygdalin*, a characteristic constituent of the seeds of drupes as well as of some other rosaceous seeds, occurs in considerable amounts in all the seeds excepting the sweet almond. The nature of the glucoside and its decomposition through the agency of the enzyme emulsin is discussed under Almond.

Ash.—Noteworthy is the relatively low potash content of the almond and the relatively high content of lime and magnesia. Figures on ash constituents of the other seeds are not available.

ALMOND

Prunus communis Fritsch = *P. Amygdalus* Stokes = *Amygdalus communis* L.

Fr. Amande. Sp. Almendra. It. Mandorla. Ger. Mandel.

The almond is grown extensively in the Mediterranean region and western Asia, where the species appears to have originated, also in California. The theory that it is a variety of the peach appears to have lost ground.

Two principal groups are recognized: the bitter (var. *amara*), from which oil of bitter almonds is made, and the sweet or edible (var. *dulcis*). Sweet almonds are either hard-shelled (var. *typica*) or thin- or paper-shelled (var. *fragilis*), the latter being now the common form grown in enormous quantities in California.

The almond may be regarded as the patrician among nuts, the peanut being the plebeian. Aside from being a common dessert nut, cracked as eaten, salted almonds, prepared by shelling, blanching, roasting, and salting, are highly esteemed. Shelled almonds are extensively used in confectionery such as sugared almonds, chocolate almonds, almond nougat, etc. The mandorlata of Venice, with honey as the base,

is famous. Bars of sweet or milk chocolate containing almonds are much in demand by travelers.

Genuine almond paste, used for the preparation of the confectionery known as macaroons, is made from the blanched kernels, sugar, etc., but too often kernels of other large-seeded drupes, notably apricot, peach, and plum, are substituted for almonds. Almond flour or meal, the ground residue after expressing almond oil, being free from starch, is used in making bread and biscuit for diabetics. Almond butter, made from the unextracted kernel, is also a diabetic food.

Immature almonds, without removal of the outer pericarp or endocarp, are candied, preserved, and pickled.

MACROSCOPIC STRUCTURE.—Varieties of almond grown as ornamentals have white or pink double flowers; those grown for fruit have large (2 to 3 cm.) pink *flowers* of the type common to all members of the genus. The *fruit* is hairy and resembles a poorly developed peach. Unlike that of the drupes grown for the succulent fruit flesh, the mesocarp at maturity is rather thin, tough, and inedible, the major part breaking away from the " nut " or endocarp. The *nut* is analogous to the stone of the peach, apricot, and plum, but the outer part of the paper-shelled varieties is soft and spongy while the inner endocarp is hard but exceedingly thin (0.5 mm.). Between the two is a middle zone containing the fibro-vascular bundles. On casual inspection these bundles appear to belong to the endocarp but on further study it is obvious that they belong to the mesocarp and correspond to the bundles which run along the bottoms of the furrows of the peach stone. The stone-cell tissue of the outer endocarp of the almond really forms ridges but the tissue is so friable that it differs little in appearance from the dry mesocarp parenchyma in the furrows covering the bundles.

On the ventral edge is a conspicuous keel within which is the bundle passing nearly to the top where it enters the locule becoming the funiculus of the pendant seed.

The *seed* varies greatly in size and ratio of breadth to length. Of the nuts shipped from Spain, Jordan (Malaga) almonds are characterized by their narrow elongated form and light brown skin; Alicanti, Valencia, and Mallorca almonds by their broad form and dark brown skin.

Only one of the two ovules ordinarily develops on ripening. Double kernels are regarded as objectionable in the confectionery trade.

MICROSCOPIC STRUCTURE. Pericarp.—As in other drupes there are four layers or zones: (1) *epicarp* with hairs, (2) *hypoderm* of polygonal cells, (3) *mesocarp* of rounded pulp cells with fibro-vascular bundles and accompanying sclerenchyma cells, and (4) *endocarp* dif-

ferentiated into an outer more or less friable and an inner hard stone-cell tissue.

The general structure of the *epicarp*, *hypoderm*, and *mesocarp* resembles that of the peach, the chief difference being that the cell walls are thicker and the hairs of the epicarp are broader at the base, being intermediate between those of the peach and the apricot.

The soft tissue which may be scraped from the surface of a paper-shelled almond consists of groups of stone cells of the *outer endocarp* and masses of mesocarp parenchyma. Most of the stone cells are isodiametric with colorless or light brown contents. The vessels of the *fibro-vascular* bundles which appear to be in the middle layer are largely pitted,

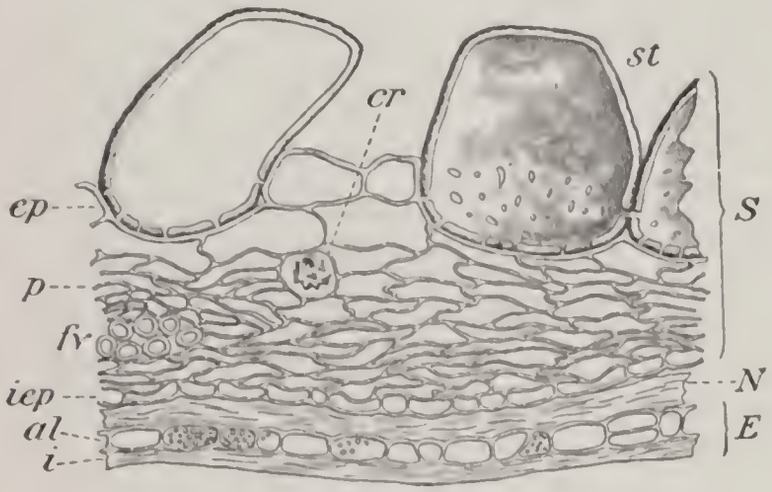


Fig. 200.

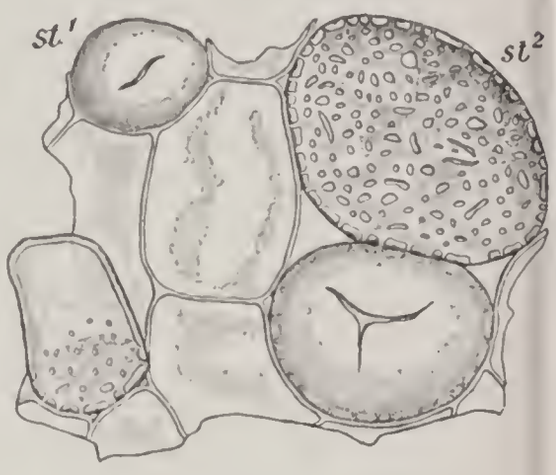


Fig. 201.

Fig. 200.—Almond. Skin of seed in cross section. *S* spermoderm. *ep* outer epiderm with *st* sclerenchyma cells, *p* parenchyma with *fv* fibro-vascular bundle and *cr* crystal cell, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *i* compressed parenchyma. ×160. (K.B.W.)

Fig. 201.—Almond. Outer epiderm of spermoderm in surface view showing st^1 outer and st^2 inner focus of sclerenchyma cells. ×160. (K.B.W.)

spiral forms being less common. These bundles as noted above belong to the mesocarp.

In the hard *inner endocarp* there is a zone of narrow, transversely elongated stone cells, within the main tissue of isodiametric stone cells, and an innermost zone of similar stone cells but with a tendency to longitudinal arrangement.

Spermoderm (Fig. 200, *S*; Fig. 201).—Of the four layers only the outer epiderm differs noticeably from the corresponding layer of the peach, nectarine, apricot, and plum. Many of the *sclerenchyma cells* (*st*) of the *outer epiderm* (*ep*) are large (as large as, or larger than, those of the peach). They are more or less truncated, noticeably thin-walled throughout—in paper-shelled almonds scarcely thickened at all although sclerenchymatous—and porous only in the inner half. The marked

truncation serves as a distinction from all the other drupes, the thin outer walls from the peach, nectarine, and plum, and the absence of pores in the outer part from the plum and apricot. Conical forms with thick outer part, such as occur in the peach, nectarine, and plum, also small rounded (dome-shaped) forms like those of the apricot are lacking. Chains of small cells, such as are found in the peach, are not evident.

The *subepiderm* consisting of a double or triple layer of polygonal cells without intercellular spaces, *spongy parenchyma* (*p*) with small vascular bundles (*fv*) and occasional crystal cells (*cr*), and small-celled *inner epiderm* (*iep*) make up the remainder of the spermoderm.

Perisperm (Fig. 200, *N*).—Only by expanding the tissues with Javelle water and staining is any cellular structure evident. The compressed cells form a colorless band in cross section.

Endosperm (Fig. 200, *E*).—One row of *aleurone cells* (*al*) and an inner band of *compressed cells* (*i*) are evident in cross section.

Embryo.—Except for the tangentially elongated epidermal cells of the cotyledon (Fig. 202) the tissues throughout are of rounded cells. Aleurone grains and fat are the visible contents. In addition to small aleurone grains each of the cells of the inner part usually contains a large aleurone grain up to 20 μ, with an oxalate rosette and a crystalloid. Globoids occur in some of the grains.

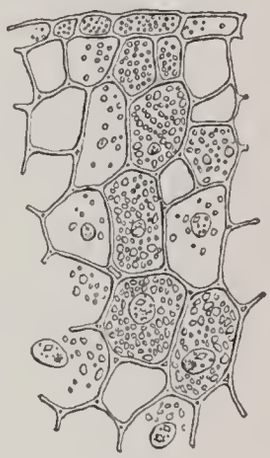


FIG. 202.—Almond. Cotyledon in cross section showing aleurone grains. ×160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Fruit flesh not edible at maturity; pericarp leathery; outer endocarp more or less friable; inner endocarp hard but thin; seed large.

Stone cells of outer endocarp in easily detached groups. Sclerenchyma cells of spermoderm large, truncated, with rather thin walls, porous only in inner half. Endosperm one cell thick. Aleurone grains of cotyledons up to 20 μ, the largest with oxalate rosette.

CHEMICAL COMPOSITION. Sweet Almond.—Colby [1] (see table on following page) analyzed 11 samples of California sweet almonds representing hard- and paper-shell varieties. The proximate constituents of husk, shell, and kernel were determined, also the ash constituents. The almond husk, which consists of the pericarp tissues corresponding to the flesh of the peach, is removed before placing the nut on the market.

[1] California Agr. Exp. Sta. 1896, Bul. **113**.

The average results of 4 analyses of European sweet almonds compiled by König [1] are: water 6.0, protein 23.5, fat 53.0, total carbohydrates 14.4, and ash 3.1 per cent.

Composition of Kernels of California Almonds (Colby)

	Kernel in nut	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Min	33*	2.0	16.6	48.9	12.8		1.6
Max	70†	5.3	25.3	60.0	21.4		2.5
Aver	55	4.8	21.0	54.9	14.3	3.0	2.0

* Hard-shell. † Paper-shell.

An analysis of the water-free kernel of Chinese sweet almonds by Ralph Langley [2] follows: protein 25.0, fat 57.3, nitrogen-free extract 11.9 (sucrose 2.1, pentosans 3.8), fiber 3.1, and ash 2.7 per cent.

Bitter Almond.—The average protein content is about 10 per cent more and the average fat content about 10 per cent less than in the sweet almond. Because of the high content of amygdalin the nuts are not edible although the press cake may be so treated as to remove the danger of hydrocyanic acid poisoning.

Almond Shells.—An analysis by Winton, Ogden, and Mitchell [3] of the shells formerly used as an adulterant of spices follows:

	%
Water	7.80
Protein (N×6.25)	1.75
Ether extract, volatile	0.16
Ether extract, non-volatile	0.64
Alcohol extract	5.16
Reducing matters *	22.72
Starch by diastase	0.84
Quercitannic acid	1.56†
Fiber	49.89
Ash, total	2.86
Ash, soluble in water	2.39
Ash, insoluble in acid	0.05

* By direct inversion. † Equivalent to 0.40 per cent of O absorbed by aqueous extract.

[1] Chem. mensch. Nahr.-Genussm. Berlin, 1903, **1**, 611.

[2] J. Am. Chem. Soc. 1907, **29**, 1513.

[3] Connecticut Agr. Exp. Sta. Rep. 1898, p. 210.

Almond Butter, Almond Meal, and Almond Paste.—Analyses of the butter and meal reported by Winton [1] and a single analysis of the paste from Jaffa's bulletin on Nuts and Their Uses as Food [2] follow:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Sugar and dextrin	Starch
	%	%	%	%	%	%	%	%
Almond butter.	0.90	22.62	61.52	8.11	3.92	2.93	3.65	0
Almond meal..	8.51	50.62	15.63	15.96	2.86	6.42	7.18	0
Almond paste..	24.2	13.1	23.9	29.4	7.8	1.6		

Proteins.—The principal protein of the almond is a globulin, *amandin*, so named by its discoverer Proust [3] but later designated conglutin and vitellin. Osborne [4] restored its original name and made preparations from the almond and peach kernels which he found to be practically identical in elementary composition.

The *Ultimate Composition of Amandin* is shown by the following average of the analyses of 4 preparations from the almond kernel:

	%
Carbon	51.37
Hydrogen	6.91
Nitrogen	19.33
Sulphur	0.45
Oxygen	21.94
	100.00

Amino Acids of Amandin.—In a preparation obtained by Harris by the extraction of the defatted seed with 0.1 saturated ammonium sulphate, precipitation by adding ammonium sulphate to 0.4 saturation, then redissolving in brine, and saturation with ammonium sulphate, Osborne and Clapp [5] separated by E. Fischer's hydrolyzation method the products tabulated at the top of the next page.

Jones, Gersdorff, and Moeller [6] obtained the following figures in almond globulin: cystine 0.85 and tryptophane 1.37 per cent.

[1] Connecticut Agr. Exp. Sta. Rep. 1906, pp. 156 and 158.
[2] U. S. Dept. Agr. 1908, Farm Bul. **332.**
[3] J. phys. chim. hist. nat. art. 1802, **56,** 97.
[4] Connecticut Agr. Exp. Sta. Rep. 1895, p. 288.
[5] Am. J. Physiol. 1908, **20,** 470.
[6] J. Biol. Chem. 1924, **62,** 183.

Products of Hydrolysis of Amandin (Osborne and Clapp)

	%
Glycocoll	0.51
Alanine	1.40
Valine	0.16
Leucine	4.45
Serine	?
Aspartic acid	5.42
Glutamic acid	23.14*
Tyrosine	1.12
Phenylalanine	2.53
Proline	2.44
Tryptophane	+
Arginine	11.85
Lysine	0.70
Histidine	1.58
Ammonia	3.70
	59.00

* Osborne and Gilbert (Ibid. 1906, **15**, 350).

Nitrogen Distribution in Amandin.—Osborne and Harris [1] report the following results by Hausmann's method: basic (di-amino) nitrogen 4.15, non-basic (mono-amino) nitrogen 11.55, nitrogen in magnesium oxide precipitate (humin) 0.17, and ammonia nitrogen 3.05; total nitrogen 19.00 per cent.

Specific Rotation of Amandin.—Osborne and Harris [2] reported −56.44.

Almond Oil is sweet and bland but owing to its high cost is seldom used as food. It is an ingredient of certain medicinal and toilet preparations. It is often adulterated with the similar oils from peach, apricot, or plum kernels which so resemble it as to render detection difficult or uncertain.

Physical and Chemical Values.—The following limits of values have been compiled from various sources:

Values of Almond Oil

	Sp. gr. 15.5° C.	Refractive index 25° C.	Solidifying point	Saponification No.	Iodine No.
			° C.		
Min	0.914	1.4680	−21	183	93
Max	0.920	1.4710	−10	196	105

[1] J. Am. Chem. Soc. 1903, **25**, 323.

[2] Ibid. 1903, **25**, 842.

A single sample used by Heiduschka and Wiesemann [1] for determining the composition of the fatty acids gave: specific gravity at 15° C. 0.918, refractive index at 25° C. 1.4693, optical rotation in 100-mm. tube −0.07, saponification number 188.8, iodine number 99.36, Hehner number 94.22, Reichert-Meissl number 0, Polenske number 0, acid number 1.24, acetyl number 5.66, glycerol 10.0 per cent, and unsaponifiable matter 0.50 per cent.

Composition.—Following is the composition of the total fatty acids as determined by the authors last named, following the alcoholic lead salt and the hexabromide methods:

	%
Palmitic acid	3.1
Oleic acid	77.0
Linolic acid	19.9
	100.0

Qualitative Reactions.—Lewkowitsch [2] states that peach and apricot oils may usually be distinguished from almond oil by the orange color formed by shaking with an equal volume of nitric acid (specific gravity 1.4) and the pink color formed by shaking 5 volumes of the oil with 1 volume of Bieber's reagent (equal weights of concentrated sulphuric acid, fuming nitric acid, and water). He warns, however, against placing entire dependence on these tests, since some lots of almond oil give misleading color reactions, and he is still more skeptical of the value of the phloroglucinol-nitric acid test.

Amygdalin ($C_{20}H_{27}O_{11}N + 3H_2O$), discovered by Robiquet and Boutron-Charlard,[3] later was studied by Liebig and Wöhler,[4] and much later by E. Fischer,[5] Caldwell and Courtauld,[6] Walker and Krieble,[7] and other investigators. Although present also in other seeds of the group, it is especially abundant in the bitter almond, the amount varying according to Thoms [8] from 2.5 to 3.5 per cent. It is split up by various reagents and by enzymes in the seed into benzaldehyde (C_7H_6O), glucose, and hydrocyanic acid.

Benzaldehyde is the chief constituent of the essential oil of bitter almonds, prepared by distillation from the seed.

[1] J. prakt. Chem. 1930, **124**, 240.
[2] Chem. Tech. Anal. Oils, etc. 1914, **2**, 291.
[3] Ann. chim. phys. 1830, **44**, 352.
[4] Annalen 1837, **22**, 1; Ann. chim. phys. 1837, **64**, 185.
[5] Ber. 1894, **27**, 2985; 1895, **28**, 1508.
[6] J. Chem. Soc. 1907, **91**, 666.
[7] Ibid. 1909, **95**, 1369, 1437.
[8] Real. Enzy. ges. Pharm. 1904, **1**, 572.

De Plato [1] states that in the bitter almond the free and loosely bound hydrocyanic acid diminishes gradually during ripening until none remains while the combined (glucosidal) hydrocyanic acid increases until the cotyledons are fully formed, then diminishes during hardening but does not completely disappear. In the sweet almond both the loosely bound and the glucosidal hydrocyanic acid decrease as the cotyledons develop and disappear during hardening. The percentage of protein nitrogen in the total nitrogen increases up to ripeness but diminishes during germination. Amygdalin appears to be an intermediate product in the formation of protein during ripening. Owing to the active metabolism in the sweet almond amygdalin is so rapidly utilized that none persists to ripeness.

Enzymes.—A single enzyme, *emulsion*, was formerly regarded as the agent in the natural splitting up of the glucoside amygdalin, but Fischer showed that two enzymes, *amygdalase* and *amygdalinase* (prunase), act successively, *mandelonitrile* (*prunasin*) being an intermediate product.

Compton [2] believes that amygdalin is decomposed in accordance with one or the other of the following reactions, depending on circumstances, I being that proposed by Emil Fischer and II being analogous to the changes brought about in vicianin by almond emulsin:

I. Amygdalin $C_{20}H_{27}O_{11}N$ —(Amygdalase)→ Glucose $C_6H_{12}O_6$ + Mandelonitrile (Prunasin) $C_{14}H_{17}O_6N$ —(Amygdalinase (Prunase))→ Benzaldehyde C_6H_5CHO + Hydrocyanic acid HCN + Glucose $C_6H_{12}O_6$

II. $C_{20}H_{27}O_{11}N$ —(Amygdalinase)→ HCN + $C_{12}H_{22}O_{11}$ (?) + C_6H_5CHO —(Amygdalase)→ $C_6H_{12}O_6$ + $C_6H_{12}O_6$

The presence of *salicinase* in the almond has been demonstrated by Bertrand and Compton [3] and the possible presence of salicin suggested.

Mineral Constituents.—Colby [4] made exhaustive analyses of husk, shell, and kernel. Although designed especially to show the amount of mineral constituents taken from the soil in a crop of nuts, they are of value in the study of plant physiology and human nutrition.

[1] Ann. staz. chim. agr. sperm. Roma, 1910, II, **4**, 117.
[2] Chem. News 1912, **106**, 163.
[3] Compt. rend. 1913, **157**, 797.
[4] Loc. cit.

Composition of Ash of California Almonds (Colby)

	Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3 †	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
Husk	1.83	64.83	0.74	4.10	5.28	4.26	0.59	5.62	1.32	12.51	0.70
Shell	1.44	64.76	2.81	9.12	5.54	3.40	0.42	7.76	3.55	2.48	0.14
Kernel	1.62	10.96	1.85	14.53	18.31	0.78	0.28	48.13	4.64	0.24	0.27

* In part ashed. † Includes Al_2O_3.

Langley [1] obtained the following percentages of constituents in the ash of Chinese sweet almonds: potash 34.60, soda trace, lime 10.70, magnesia 13.80, manganic oxide trace, and phosphoric acid 37.50; total 96.60 per cent. It should be noted that he found much more potash and much less phosphoric acid than Colby. An analysis in König's compilation [2] shows intermediate amounts of these constituents.

Minor Mineral Constituents. *Iron.*—Peeled 47 mg. per kilo, as sold (Häusermann quoted by Sherman).[3]

Manganese.—Sweet almonds, kernel 8.06, shell 5.3 mg. per kilo, dry basis (Quartaroli).[4]

Copper.—Almond, sweet 14, bitter 13 mg. per kilo (Guerithault).[5] Sweet, kernel 15.15, shell 3.8 mg. per kilo, dry basis (Quartaroli).[4]

Zinc.—Whole fresh almonds 10, fresh pericarp 3.8, dried kernel 18.5, dried tegument 23.7, dried shells 4.2 mg. per kilo (Bertrand and Benzon).[6]

PEACH KERNEL

Prunus persica Sieb et Zucc. = *Amygdalus persica* L. = *Persica vulgaris* Mill.

The fruit pulp and shell of the pit are described in Volume II.

MACROSCOPIC STRUCTURE.—The *seed* resembles a small almond of the broader type. It conforms to the general group characters described under Drupes.

MICROSCOPIC STRUCTURE. Spermoderm. (Fig. 203, *S*; Fig. 204).—Both the sclerenchyma (*st*) and parenchyma cells of the *outer epiderm* (*ep*), seen in surface mounts, are mostly large (up to 150 μ or more), the former as noted by Hannig [7] showing pores only in the inner

[1] Loc. cit.

[2] Chem. mensch. Nahr.-Genussm. 1920, II, 874.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **85.**

[4] Ann. chim. appl. 1928, **18,** 47.

[5] Compt. rend. 1920, **171,** 196.

[6] Bul. soc. hyg. aliment. 1928, **16,** 457.

[7] Z. Unters. Nahr.-Genussm. 1911, **21,** 577.

part so that when focusing on the outer wall pores are not evident. Young [1] correctly observes that in addition to the large sclerenchyma cells there are smaller ones (about 50 μ) arranged in rows adjacent to the bundles. As stated by Wittmack and Buchwald [2] the sclerenchyma cells in cross section are strikingly conical. This feature, together with the thickened non-porous outer part (noted by Hannig), and the large size suffices usually for their identification in almond pastes or confectionery.

The remaining three layers of the spermoderm are not distinguishable

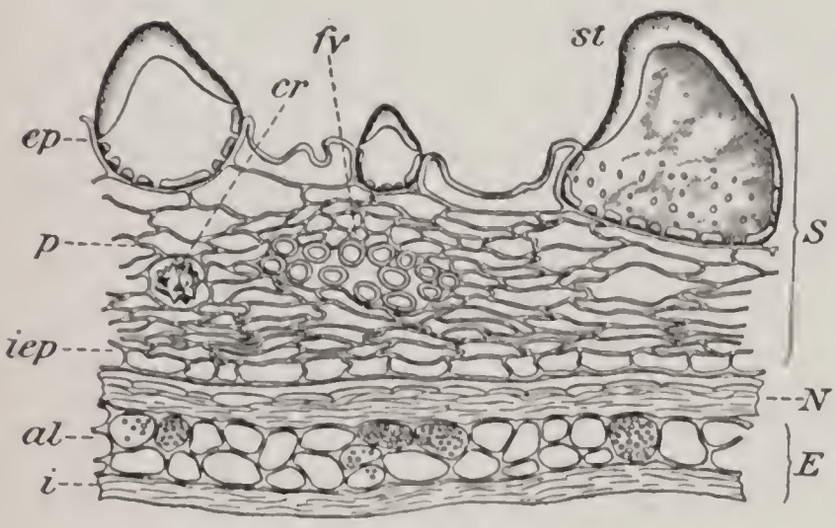


Fig. 203.

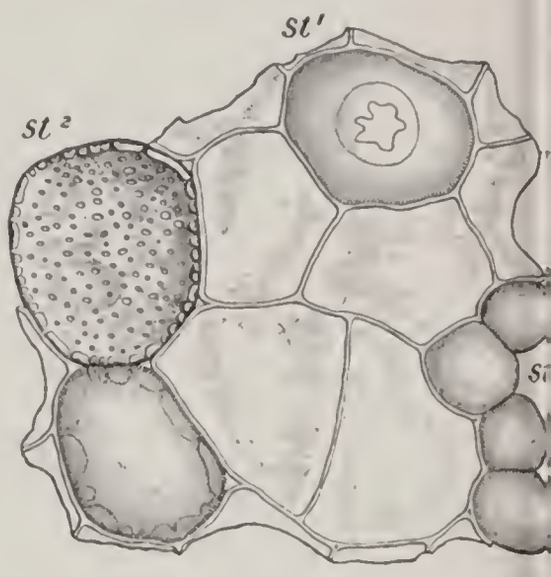


Fig. 204.

Fig. 203.—Peach. Skin of seed in cross section. *S* spermoderm: *ep* outer epiderm with *st* sclerenchyma cells, *p* parenchyma with *fv* fibro-vascular bundle and *cr* crystal cell, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *i* compressed parenchyma. ×160. (K.B.W.)

Fig. 204.—Peach. Outer epiderm of spermoderm in surface view showing st^1 outer and st^2 inner focus of sclerenchyma cells, also st^3 chain of small sclerenchyma cells. ×160. (K.B.W.)

from the corresponding layers of the nectarine, almond, apricot, and plum.

Perisperm (Fig. 203, *N*).—*Compressed cells* forming in cross section a hyaline band.

Endosperm (Fig. 203, *E*).—Usually the *aleurone cells* (*al*) of the outer layer are only one to three thick. The inner endosperm is of *compressed cells* (*i*) forming a colorless band.

Embryo.—As in other drupes.

Chief Structural Characters.—Epidermal sclerenchyma cells of spermoderm conical, mostly large, less often small in rows, outer wall

[1] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160.**

[2] B. deut. bot. Ges. 1901, **19,** 584.

thickened but not porous. Aleurone cells of endosperm one to three cells thick.

CHEMICAL COMPOSITION.—Meager information on the composition of the kernels and of the residues from the manufacture of the fatty oil and the volatile oil is on record.

Alpers [1] states that the kernel forms only 5.7 per cent of the pit and that it contains 45.45 per cent of fatty oil and 26.01 per cent of protein. Rabak [2] gives 39.5 per cent as the yield of fatty oil in the kernel.

Proteins.—The chief protein is the globulin *amandin*, the ultimate analysis of which, according to Osborne,[3] corresponds so closely with that from the almond as to warrant his conclusion that the two globulins are identical. He found in his preparation:

	%
Carbon	51.30
Hydrogen	6.90
Nitrogen	19.32
Sulphur	0.44
Oxygen	22.04
	100.00

Fatty Oil. *Physical and Chemical Values.*—The following limits are based on results by De Negri and Fabris,[4] Micko,[5] and Alpers:[1]

	Sp. gr. 15.5° C.	Refractive index 25° C.	Solidifying point	Saponification No.	Iodine No.
			° C.		
Min	0.918	1.4695	−20	187	92
Max	0.923	1.4705	−10	193	110

Volatile Oil.—A sample distilled by Rabak [2] showed specific gravity at 25° C. 1.068, hydrocyanic acid 2.20 per cent, and benzaldehyde 73.1 per cent.

Amygdalin.—See Almond.

According to Thoms,[6] 2.35 per cent of amygdalin is present in the kernel.

[1] Z. Unters. Nahr.-Genussm. 1917, **34**, 433.
[2] U. S. Dept. Agr., Bur. Plant Ind. 1908, Bul. **133**.
[3] Connecticut Agr. Exp. Sta. Rep. 1895, p. 288.
[4] Ann. chim. centr. Gabelle, **2**, Gli Olii, 1891, 1893; Z. anal. Chem. 1894, **33**, 547.
[5] Z. allg. oesterr. Apoth.-Ver. 1893, **31**, 175.
[6] Real-Enzy. ges. Pharm. 1904, **1**, 572.

Huber [1] determined the hydrocyanic acid formed in the kernel by enzyme action and from this the equivalent amount of amygdalin with average results respectively as follows: 0.151 and 2.65 per cent.

NECTARINE KERNEL

Prunus Persica var. *nucipersica* Schneid. = *Persica nucipersica* Borkh.

The fruit flesh is described in Volume II.

MACROSCOPIC STRUCTURE.—The *pit* is like that of the peach.

MICROSCOPIC STRUCTURE. Spermoderm.—The sclerenchyma cells of the *outer epiderm* are about the same diameter at the base and often of the same conical shape as those of the peach but some have much greater radial elongation, reaching often 400 μ for cells with a basal diameter of scarcely 100 μ. These much-elongated cells taper gradually to a truncated end, the wall of which is not greatly thickened. Among the conical sclerenchyma cells with thick outer walls similar to those of the peach are some which like the plum have pores in the outer walls.

Endosperm.—The aleurone layer varies in thickness up to eight or ten cells. It thus appears that the structure of both the outer epiderm of the spermoderm and the endosperm is intermediate between that of the peach and the plum.

Embryo.—As in other drupes.

Chief Structural Characters.—Epidermal sclerenchyma cells of spermoderm partly conical with thick, porous outer half, partly radially elongated up to 400 μ. Aleurone layer of endosperm varies in thickness up to eight or ten cells. Distinctions from other members of the group noted under Drupes.

APRICOT KERNEL

Prunus Armeniaca L. = *Armeniaca vulgaris* Lam.

A full description of the edible fruit is given in Volume II.

MACROSCOPIC STRUCTURE.—The bitter-tasting *seed* is rounded or heart-shaped, about equal in length and breadth. Although often as broad as the almond kernel, it is much shorter. In general structure it conforms to the almond and other drupes.

MICROSCOPIC STRUCTURE. Spermoderm (Fig. 205, *S*; Fig. 206).—Only the sclerenchyma cells (*st*) of the *outer epiderm* (*ep*) are notice-

[1] Landw. Vers.-Stat. 1911, **75**, 462.

ably different in the apricot from those in other drupes. Surface mounts show that these sclerenchyma cells are smaller than many found in the almond and peach but about the same size as those of the plum. From the latter they are distinguished by the dome-shaped, not thickened, outer wall, as seen in cross section. This outer wall is porous as in the plum and nectarine.

Perisperm (Fig. 205, *N*).—*Compressed cells* as in other drupes.

Endosperm (Fig. 205, *E*).—A layer of *aleurone cells* (*al*), only one cell thick, and a layer of *compressed cells* (*i*) are present, whereas in the

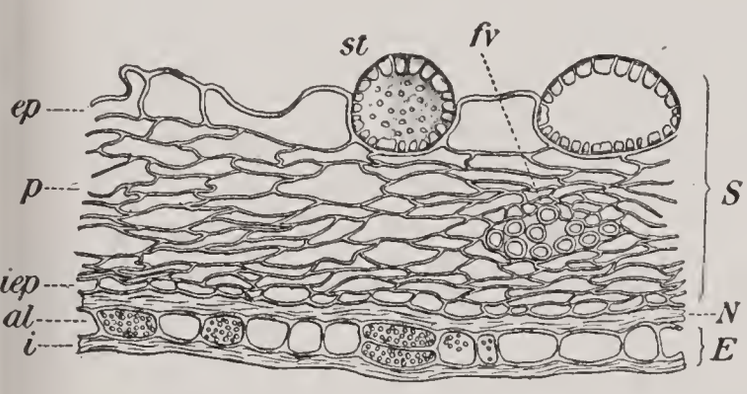


Fig. 205.

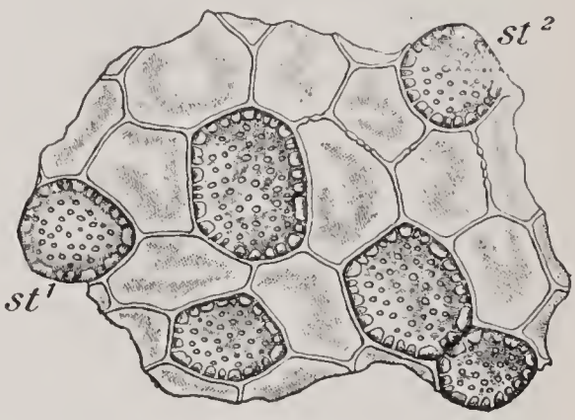


Fig. 206.

Fig. 205.—Apricot. Skin of seed in cross section. *S* spermoderm: *ep* outer epiderm with *st* sclerenchyma cells, *p* parenchyma with *fv* fibro-vascular bundle, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *i* compressed parenchyma. ×160. (K.B.W.)

Fig. 206.—Apricot. Outer epiderm of spermoderm in surface view showing st^1 outer and st^2 inner focus of sclerenchyma cells. ×160. (K.B.W.)

plum the aleurone layer may reach twenty cells in thickness on the sides of the seed.

Embryo.—As in the plum.

Chief Structural Characters.—Epidermal sclerenchyma cells of spermoderm small, dome-shaped, with thin, porous outer walls. Aleurone cells of endosperm one cell thick. Distinctions from other members of the group noted under Drupes.

CHEMICAL COMPOSITION.—Analysis by Rosenthaler and Schaeffer [1] gave: water 4.33, protein 31.4, oil 53.4, sugar as dextrose direct 8.08 and after inversion 11.64, total extract 27.87, fiber 4.76, and ash 2.60 per cent.

According to Alpers [2] the pit contains 29.2 per cent of kernel and the kernel 51.43 per cent of oil and 28.36 per cent of protein.

[1] Pharm. Zentralb. 1911, **52**, 507.

[2] Z. Unters. Nahr.-Genussm. 1917, **34**, 433.

Ueno [1] in the kernels of Mongolian apricot pits (forming 66.7 per cent of the pits) and Chinese apricot pits found respectively: water 7.89 and 2.79, oil 54.02 and 53.03 per cent. In the dry kernel of Roumanian apricots Mircescu [2] found 58 per cent of oil.

Fatty Oil. *Physical and Chemical Values.*—The following have been compiled from various sources, including those named above; also De Negri and Fabris and Micko (see Peach):

	Sp. gr. 15.5° C.	Refrac. index 25° C.	Solidifying point	Saponification No.	Iodine No.	Reichert-Meissl No.	Hehner No.
			° C.				
Min.	0.917	1.4691*	−20	188	95	1.07	73.5
Max.	0.921	1.4730	5	199	109	1.07	73.5

* Rosenthaler and Schaeffer report 1.4617.

A single sample used by Heiduschka and Wiesemann[3] for determining the composition of the fatty acids gave: specific gravity at 15° C. 0.9181, refractive index at 25° C. 1.4697, optical rotation in 100-mm. tube −0.07, iodine number 101.6, Polenske number 0, acid number 3.26, glycerol 10.73 per cent, and unsaponifiable matter 0.43 per cent.

Ueno's values for Japanese oil[4] and for Mongolian oil[1] fall within the above limits, but those for the Chinese oil do not, being as follows: specific gravity at 15.5° C. 0.910, refractive index at 25° C. 1.4641, saponification number 182.3, and iodine number 90.4.

Mircescu [2] reports 74.04 per cent of liquid acids melting at −10 to 0° C. and 14.34 per cent of solid acids melting at 22 to 33° C.

Composition.—Following is the composition of the total fatty acids as determined by Heiduschka and Wiesemann, following the alcoholic lead salt and the hexabromide methods:

	%
Palmitic acid	2.08
Oleic acid	79.39
Linolic acid	18.53
Linolenic acid	0.00
	100.00

[1] J. Chem. Ind. Japan 1918, **21**, 525.
[2] Bul. soc. chim. România 1926, **8**, 28.
[3] J. prakt. Chem. 1930, **124**, 240.
[4] J. Chem. Ind. Japan 1913, **16**, 656.

Enzymes.—Traetta-Mosca, Papocchia, and Galimberti,[1] found *emulsin* present in all stages of ripening. Willstätter and Csányi,[2] after a study of emulsin reactions, conclude that their preparations made from both apricots and bitter almond kernels contained several enzymes that serve to decompose glucosides and polyoses.

PLUM KERNEL

Prunus domestica L. = *P. communis* Huds.

Classification of plums, also the structure and composition of their fruit tissues and endocarp, are treated in Volume II.

MACROSCOPIC STRUCTURE.—The *seed* varies in the ratio of length to breadth but is usually narrower than those of the apricot

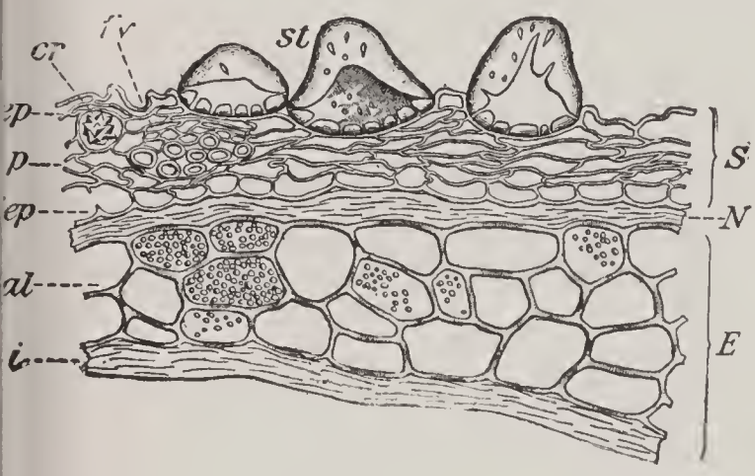


Fig. 207.

Fig. 208.

Fig. 207.—European Plum. Skin of seed in cross section. *S* spermoderm: *ep* outer epiderm with *st* sclerenchyma cells, *p* parenchyma with *fv* fibro-vascular bundle and *cr* crystal cell, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *i* compressed parenchyma. ×160. (K.B.W.)

Fig. 208.—European Plum. Outer epiderm of spermoderm in surface view showing st^1 outer and st^2 inner focus of sclerenchyma cells. ×160. (K.B.W.)

and peach and is much smaller than that of the almond. It is more or less pointed at the radicle end.

MICROSCOPIC STRUCTURE. Spermoderm (Fig. 207, *S*; Fig. 208).—The four layers are as follows: (1) *outer epiderm* (*ep*) of large polygonal, thin-walled cells and conical sclerenchyma cells (*st*) with thick, porous outer walls, (2) *subepiderm* of thin-walled polygonal cells, (3) *spongy parenchyma* (*p*), sometimes with crystal rosettes (*cr*), through which run the fibro-vascular bundles (*fv*), and (4) *inner epiderm* (*iep*) of small, polygonal, thin-walled cells.

[1] Ann. chim. appl. 1923, **13**, 333.
[2] Z. physiol. Chem. 1921, **117**, 172.

Characteristic of the *epidermal sclerenchyma cells* is their small size, conical form, and thickened outer walls with pores. In neither the almond nor the peach are pores present in the outer wall, although in the peach the outer walls are thickened and conical. On the other hand, pores occur in the outer walls of the sclerenchyma cells of the apricot and nectarine but these walls in the apricot are thin and the cells, although small, are dome-shaped, not conical, whereas in the nectarine, except for the pores, the cells are of the peach type. Neither the plum nor the apricot has such large sclerenchyma cells as the almond, the peach, and the nectarine. Observed in surface mounts (Fig. 208), the sclerenchyma cells, whether the focus is on the outer or the inner wall, present a characteristic appearance because of the points mentioned.

The other spermoderm layers are not distinguishable from the corresponding layers of the almond, peach, nectarine, and apricot.

Perisperm (Fig. 207, *N*).—In cross section this forms a band of compressed tissue.

Endosperm (Fig. 207, *E*).—As many as fifteen to twenty layers of *aleurone cells* (*al*) are present on the broad side of the seed, diminishing to one or two on the edges. Within this is a band of *compressed parenchyma* (*i*).

Embryo.—Longitudinally elongated cells form the *outer epiderm* of the cotyledons. The remaining cells are isodiametric-rounded with small intercellular spaces at the angles. The visible contents are aleurone grains and fat. In the epiderm the aleurone grains are small (up to 5 μ), further inward each cell contains in addition a larger grain (up to 20 μ). Globoids are present in both large and small grains and a crystalloid or calcium oxalate rosette in each of the large grains.

Chief Structural Characters.—Epidermal sclerenchyma cells of spermoderm small, conical, with porous, thickened outer walls. Aleurone cells of endosperm varying from one or two cells in thickness on edge to twenty on broad side of seed. Distinctions from other members of the group noted under Drupes.

CHEMICAL COMPOSITION.—The data on the percentage of the parts and the composition of the kernel tabulated on the following page are by Feruglio and Bernardis [1] and Alpers: [2]

Kassner [3] secured a yield of 24.48 per cent of expressed oil from the dried pits.

[1] Bol. ass. agr. fruil. 1916, **31**, 56.

[2] Z. Unters. Nahr.-Genussm. 1917, **34**, 433.

[3] Arch. Pharm. 1918, **256**, 106.

	Samples	Pit in fruit	Kernel in pit	Water in kernel	Protein in kernel	Oil in kernel
		%	%	%	%	%
F. and B.:						
Min.	.....	.....	.....	.....	24.81	42.61
Max.	.....	4.82	26.7	.....	26.81	45.69
Alpers:	22					
Min.	.....	2.3	5.00	3.06	21.36	26.72
Max.	.....	6.0	22.20	17.76	33.61	49.57
Aver.	.....	**4.1**	**12.55**	**9.17**	**23.78**	**37.38**

Fatty Oil. *Physical and Chemical Values.*—The following limits are based on results by De Negri and Fabris and by Micko (see Peach) and Alpers:[1]

	Sp. gr. 15.5° C.	Refractive index 25° C.	Solidifying point	Saponification No.	Iodine No.
			° C.		
Min.	0.912	1.4679	−10	189	91
Max.	0.922	1.4701	−5	192	121*

* This result by Alpers; the maximum of other authors is 109.

Feruglio and Bernardis[2] note that the values differ little from those of olive oil and that the oil consists largely of glycerides of oleic acid with small amounts of glycerides of linolic and palmitic acids.

Amygdalin.—See Almond.

Thoms[3] reports 0.96 per cent of amygdalin in the kernel.

Huber[4] determined the hydrocyanic acid formed in the kernel by enzyme action and from this the equivalent amount of amygdalin with average results respectively as follows: small blue plum 0.278 and 4.70, large yellow-green gage 0.297 and 5.03, small German prune 0.171 and 2.89, and large Welch plum 0.257 and 4.33 per cent.

Enzymes.—Emulsin is present in the plum in such amount as to lead Helferich[5] to choose this material for its preparation.

[1] Loc. cit.
[2] Loc. cit.
[3] Real. Enzy. ges. Pharm. 1904, **1**, 572.
[4] Landw. Vers.-Stat. 1911, **75**, 462.
[5] Z. physiol. Chem. 1921, **117**, 159.

SWEET CHERRY KERNEL

Prunus avium L. = *P. Cerasus* L. var. *avium* L. = *C. avium* Moench.

The fruit flesh and endocarp (or shell of pit) are described in Volume II.

MACROSCOPIC STRUCTURE.—The *kernel* or seed is globular, smooth, and so small as to render utilization, except perhaps for oil manufacture by extraction, impracticable.

MICROSCOPIC STRUCTURE. Spermoderm. (Fig. 209, *S*).—Especially characteristic is the presence of sclerenchyma cells in the subepiderm as well as in the outer epiderm. This distinguishes both sweet and sour cherries from the larger drupes.

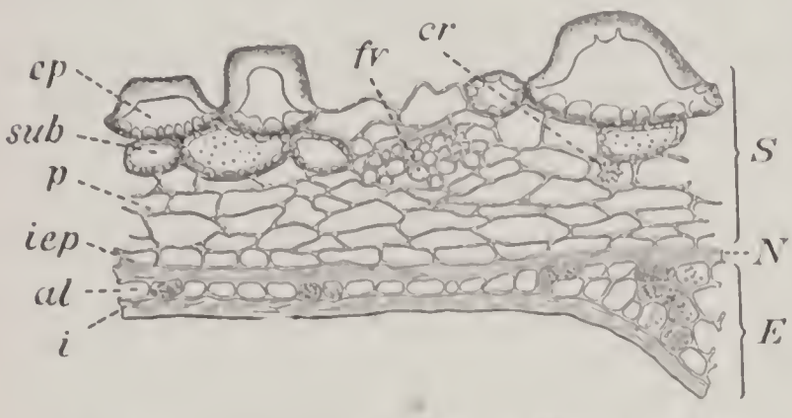


Fig. 209.—Sweet Cherry. Skin of seed in cross section. *S* spermoderm: *ep* outer epiderm with sclerenchyma cells, *sub* subepiderm, *p* parenchyma with *fv* fibrovascular bundle and *cr* crystal cell, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *i* compressed parenchyma. ×160. (K.B.W.)

In surface view the sclerenchyma cells of the *epiderm* are large, more angular than in the larger drupes, and may even have projections at the angles. Cross sections (*cp*) bring out projections at the base and the more or less flat top, making the whole cell hat-shaped, also the thickening of the walls on all sides and the pores present sometimes in the outer as well as the inner wall. Unlike the sour cherry, the radial diameter of the cells often equals the breadth. Another distinction from the sour cherry lies in the thicker walls.

Sclerenchyma cells occur in patches in the *subepiderm* (*sub*). They are more numerous, smaller, and have thinner walls, which are porous throughout, than those of the epiderm.

Crystal rosettes (*cr*) are not so numerous in the parenchyma as they are in the parenchyma of the sour cherry.

Perisperm (Fig. 209, *N*).—As in other drupes.

Endosperm (Fig. 209, *E*).—Like that of the plum, the *aleurone layer* (*al*), one cell thick on the edges, broadens out to several thick on the flat sides of the seed.

Embryo.—Much as in other drupes.

Chief Structural Characters.—Seed small, globular.

Epidermal sclerenchyma cells of spermoderm large, hat-shaped,

thick-walled on all sides, outer wall sometimes porous; subepidermal sclerenchyma cells numerous, rather thin-walled, porous throughout (subepidermal sclerenchyma cells absent in other drupes). Aleurone cells of endosperm one cell thick on edge of seed, several thick on flat side.

CHEMICAL COMPOSITION.—Alpers [1] examined 13 samples with the following results:

	Kernel in stone	Water in kernel *	Protein in kernel *	Fat in kernel
	%	%	%	%
Min.	16.28	5.36	23.27	35.30
Max.	33.00	7.80	33.40	43.30
Aver.	**22.93**	**6.30**	**28.01**	**38.71**

* Ten samples.

Maxwell [2] obtained 37.6 per cent of fatty oil in the kernel by ether extraction.

Fatty Oil.—The *Physical and Chemical Values* of the fatty oil of the kernel have been determined by the authors named above and by De Negri and Fabris and by Micko (see Peach):

	Sp. gr. 15.5° C.	Refractive index 25° C.	Solidifying point	Sapon. No.	Iodine No.	Fatty acids, titer
			° C.			° C.
Min.	0.921	1.4751	−20	193	110.0	13
Max.	0.938	1.4766	−19	195	122.6	15

As in the case of plum kernel oil, the highest iodine number is by Alpers; the results of other observers fall below 115.

Amygdalin.—See Almond.

Thoms [3] states that the kernel contains 0.82 per cent of amygdalin.

Enzymes.—Huber [4] determined the hydrocyanic acid formed in the kernel by enzyme action and from this the equivalent amount of amyg-

[1] Z. Unters. Nahr.-Genussm. 1917, **34**, 433.
[2] Chem. News 1918, **117**, 122.
[3] Real. Enzy. ges. Pharm. 1904, **1**, 572.
[4] Landw. Vers.-Stat. 1911, **75**, 462.

dalin with average results respectively as follows: 0.112 and 1.91 per cent.

Tractta-Mosca, Papocchia, and Galimberti[1] found *emulsin* present in all stages of growth.

SOUR CHERRY KERNEL

Prunus Cerasus L. = *Cerasus vulgaris* Mill.

See Volume II for description of fruit flesh.

The structure of the kernel differs from that of the sweet cherry in that the sclerenchyma cells of the spermoderm are relatively lower and thinner-walled and the parenchyma layer contains a greater number of oxalate crystals.

[1] Ann. chim. appl. 1923, **13**, 333.

SEEDS OF THE PEA FAMILY

(*Leguminosæ*)

Two species of this family, the peanut and soy bean, although valuable also for their edible seeds and as forage plants, are among the leading species yielding vegetable oil.

Characteristics of the group and of the seeds of the garden species are described in Volume II under Vegetables, the plants used for forage, in this volume under Forage Legumes.

COMPARATIVE CHEMICAL COMPOSITION.—The two oil seeds of this group are radically different in their ratios of protein to fat and also in the percentage composition of the fat, although qualitatively much alike. Shelled peanuts average 1.5 times as much fat as protein, whereas soy bean contains 2.5 times as much protein as fat.

Proteins.—The chief proteins of the peanut are arachin and conarachin, both globulins; the chief protein of the soy bean is glycenin, also a globulin.

Oil.—Peanut oil has an iodine number of 90 to 95, soy oil of 115 to 142. Peanut oil contains 53 to 61 per cent of olein and 22 to 25 per cent of linolein, whereas soy oil contains 21 to 33 per cent of olein and 50 to 57 per cent of linolein; in other words the figures given for one oil reversed apply to the other.

Carbohydrates.—The peanut contains about 6 per cent of starch; the soy bean usually contains none.

PEANUT

Arachis hypogæa L.

Fr. Arachide. Sp. Cacahuate. It. Arachide. Ger. Erdnuss.

A native of Brazil, the peanut or earth nut is at once the most remarkable of the legumes in habits and structure and one of the most valuable for food, oil, and forage. It is now grown throughout the tropics and the warmer regions of the temperate zone.

Large-seeded peanuts are produced in large quantities in Virginia. Throughout the United States they are roasted in small lots in special apparatus maintained by venders and sold in the shell, often while hot.

They are also roasted on a large scale and shelled by machinery. The meats are consumed in large quantities merely salted, also in confectionery, cakes, and biscuits. Peanuts ground to a paste, known as "peanut butter," furnish a modern spread for bread. Peanut shells have been used to adulterate feed stuffs.

Small-seeded Spanish and African varieties are largely used for oil production, although Spanish peanuts are successfully grown on a small scale in the latitude of New York for roasting nuts. The cake obtained as a by-product is used in some countries, notably Spain, for human food but is most widely known as a concentrated cattle food.

The stalks, leaves, and immature pods are dried as hay. See Part III,

Fig. 210.

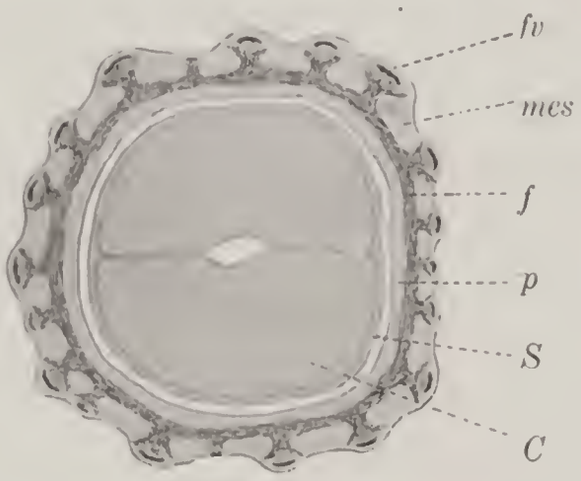


Fig. 211.

Fig. 210. Peanut. Fruit. ×1. (A.L.W.)

Fig. 211.—Peanut. Fruit in cross section. Pericarp: *mes* outer mesocarp, *f* fiber layer, *p* inner parenchyma of mesocarp, *fv* fibro-vascular bundle. *S* spermoderm. *C* cotyledon. ×4. (A.L.W.)

Forage Plants, where the structure and composition of the leaves, stalk, and flowers are described.

MACROSCOPIC STRUCTURE (Figs. 210 and 211).—Peanuts are one- to several-seeded *pods* which, after fertilization of the ovules, have been forced under ground by the subsequent growth downward of a fruit stalk (stipe). Commonly they are two-seeded, less often three-seeded, and only in certain unusual varieties such as are grown in Costa Rica are they four- or five-seeded.

The *shell* or pericarp is brittle, pale yellow, buff, or orange. A number of longitudinal ridges, connected here and there by branches, form reticulations on the surface. The framework of these reticulations is fibrous tissue projecting from a fibrous zone (*f*) which forms the middle coat of the pod. A fibro-vascular bundle (*fv*) runs in a groove formed by the fibers of the ridges. On the inner surface is a papery tissue with a silky luster (*p*).

Owing to crowding during growth, the adjoining ends of the *seeds* are flattened, usually diagonally. The small hilum of each seed is in the end nearest the stem of the pod, the chalaza near the other end. Enveloping each seed is a thin skin (*S*), copper-colored, brown, or purple on the outer, yellow or white on the inner side. This consists chiefly of spermoderm with an inner layer believed to be endosperm. In this skin the raphe and its branches—about five—radiating from the chalaza are evident as veins. Each of the elongated cotyledons (*C*) has a longitudinal groove through the middle of the inner side. The radicle is short and not recurved.

MICROSCOPIC STRUCTURE.—Moeller,[1] Vogl,[2] and Hanausek[3] confined their descriptions to the seed; Böhmer,[4] Kobus,[5] Uhlitzsch,[6]

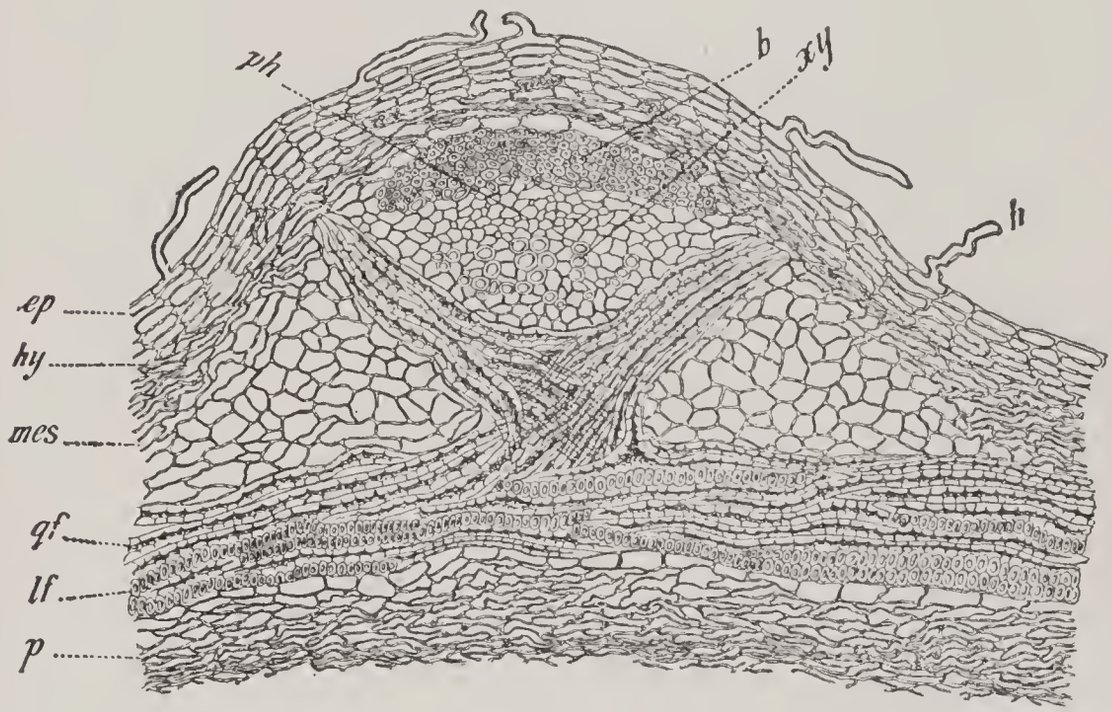


FIG. 212.—Peanut. Pericarp in cross section through a rib. *ep* epicarp with *h* hair; *hy* hypoderm; *mes* mesocarp; *qf* transversely elongated fibers; *lf* longitudinally elongated fibers; *p* parenchyma; *b* bast fibers; *ph* phloem and *xy* xylem of a fibro-vascular bundle. ×80. (A.L.W.)

and Collin and Perrot [7] included also the pericarp; Winton [8] brought to notice the root hairs and branching fibers of the pericarp.

Pericarp.—In cross section (Fig. 212) the tissues are seen to form five

[1] Mikroskopie Nahr.-Genussm. Berlin, 2 Aufl. 1905, p. 288.
[2] Wicht. Nahr. Genussm. Berlin, 1899, p. 239.
[3] Microscopy of Technical Products. New York, 1907, p. 389.
[4] Dammer's Lexikon, p. 680.
[5] Landw. Jahrb. 1884, **13**, 813.
[6] Landw. Vers.-Stat. 1892, **41**, 385.
[7] Les résidus industriels. Paris, 1904, p. 223.
[8] Connecticut Agr. Exp. Sta. Rep. 1904, p. 191.

layers: (1) *epicarp* (*ep*) of exceedingly thin-walled cells, many with typical root hairs (*h*), (2) *hypoderm* (*hy*) of more or less rectangular cells, thin-walled and non-porous without, thicker-walled and porous within, in cork-like radial rows, (3) *mesocarp* (*mes*) or outer parenchyma, interrupted by the ridges, (4) *fiber layer* of transversely (*qf*) and longitudinally (*lf*) elongated simple fibers and curious T-shaped forms, forming the channeled ridges in which run the fibro-vascular bundles, and (5) *inner parenchyma* (*p*) of pith-like, thin-walled, rounded cells, with intercellular spaces at the angles, collapsed at maturity.

Hairs of the root type proceeding from the center of epicarp cells without partitions are unique whether or not these function as absorptive organs. They are largely rubbed off in cleaning and handling. The absence of stomata and chlorophyl grains shows that photosynthetic power is lacking.

Great diversity of form, best seen in macerated material, characterizes the elements of the *fiber layer*. The fibers of one group, such as shown in Fig. 213 (*f*), lie in between the saw-teeth of a crossing layer (*z*). The T-shaped forms (*t*), often occurring in series, serve to strengthen the ridges. Halberd-shaped (*h*), grotesque (*g*), and thin-walled (*d*) fibers, as well as typical stone cells (*k*) also occur.

The bast fibers (Fig. 212, *b*), in the group outside the fibro-vascular bundle, are of small diameter. Vessels of various types form the xylem (*xy*) and typical elements the phloem (*ph*).

Spermoderm (Fig. 214 *S*; Fig. 215).—Although modified in some degree the tissues are of the leguminous type and form four layers: (1) *outer epiderm* (*aep*) corresponding to the palisade cells of other legumes but not so high, up to 25 μ, and broader, up to 50 μ, with thick, porous walls in the outer part, (2) *subepiderm* (p^1) of thin-walled polygonal-celled parenchyma (not spool-shaped), (3) *spongy parenchyma* varying from the usual type (p^2) with moderate-sized intercellular spaces to striking narrow branched cells (p^3), and (4) *inner epiderm* brought out in both cross sections and scrapings by bleaching with Javelle water and staining with safranin.

Surface preparations of the *outer epiderm* show strikingly the thick, porous radial walls and the broad lumen. A sclerenchyma group beneath the hilum slit is not evident.

Quite possibly further investigation may show that the layer here described as *inner epiderm* may be perisperm. In surface view the cells are usually quadrilateral, often elongated and in rows.

Endosperm (Figs. 214 and 215, *N*).—A single layer of moderately thick-walled cells with slightly wavy contour forms the inner coat of the skin. Hanausek found corroded crystals in the cells. This layer was

regarded by Harz as endosperm, by Böhmer as inner epiderm of the spermoderm, and by Vogl, Collin and Perrot, and Winton as perisperm, but is here considered to be endosperm, analogous to the corresponding layer of certain other legumes.

Embryo (Figs. 214 and 215).—The *epiderms* (*ep*) of the cotyledon (*C*) consist of tangentially elongated cells with minute aleurone grains

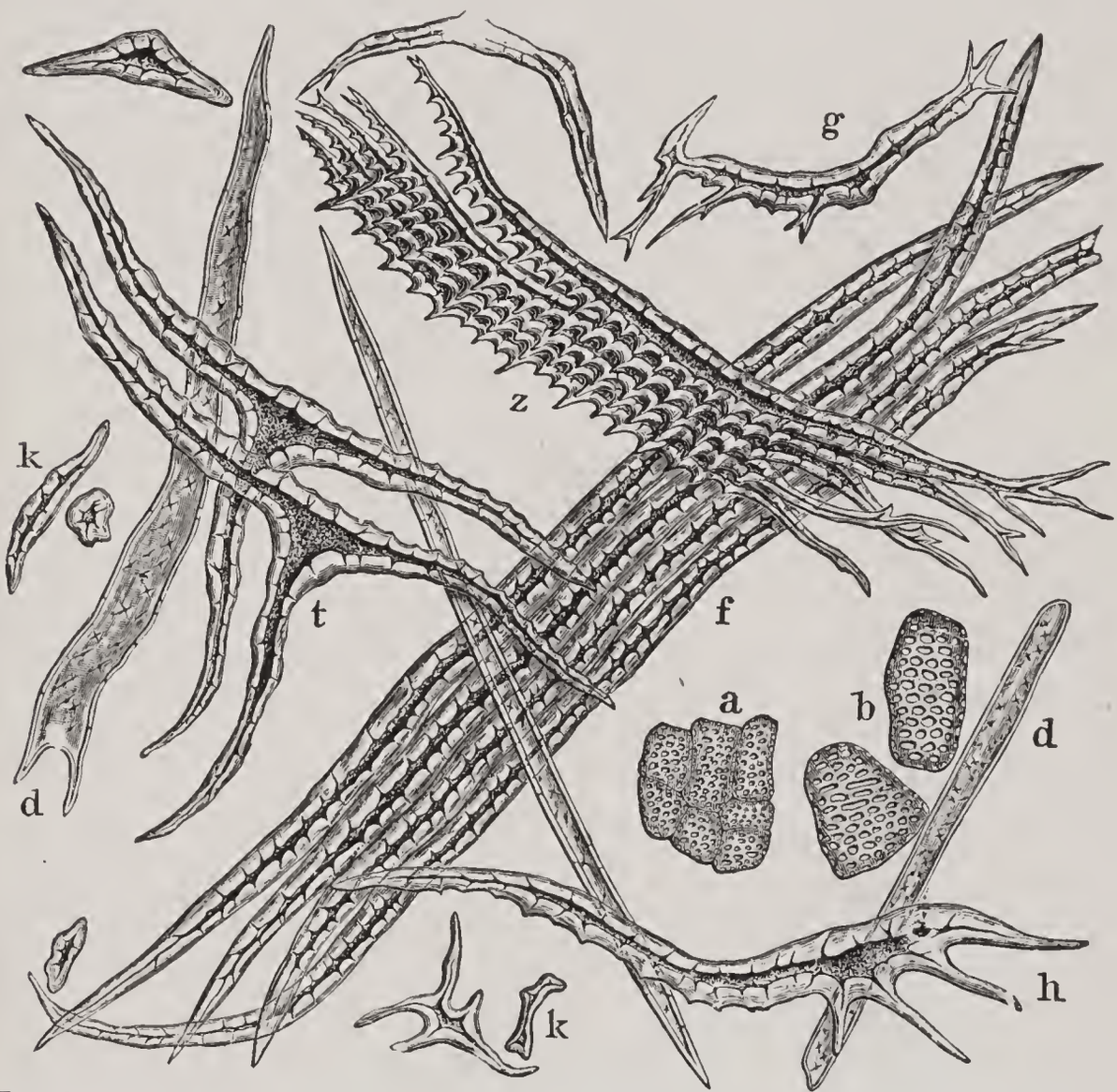


FIG. 213.—Peanut. Isolated elements of the pericarp. *a*, *b* cells of hypoderm; *f*, *z*, *k*, *h*, *t*, *d*, *g* elements of the fiber layer. ×160. (A.L.W.)

and stomata (*sto*) with small starch grains in the guard cells. The *mesophyl* has thick porous cell walls throughout. Palisade cells are lacking. *Starch grains* up to 15 μ of globular form with a central hilum and aleurone grains (*al*), also up to about 15 μ, with several globoids in the largest, and fat are the evident contents.

CHIEF STRUCTURAL CHARACTERS.—Pericarp buff or orange, reticulated, dry, and spongy within; spermoderm and endosperm forming skin, copper-colored, brown, or purple on the outer surface, yellow or white on inner.

Epicarp with root hairs; inner hypoderm cells rectangular and porous; fibers in crossing groups, T-shaped, toothed, halberd-shaped,

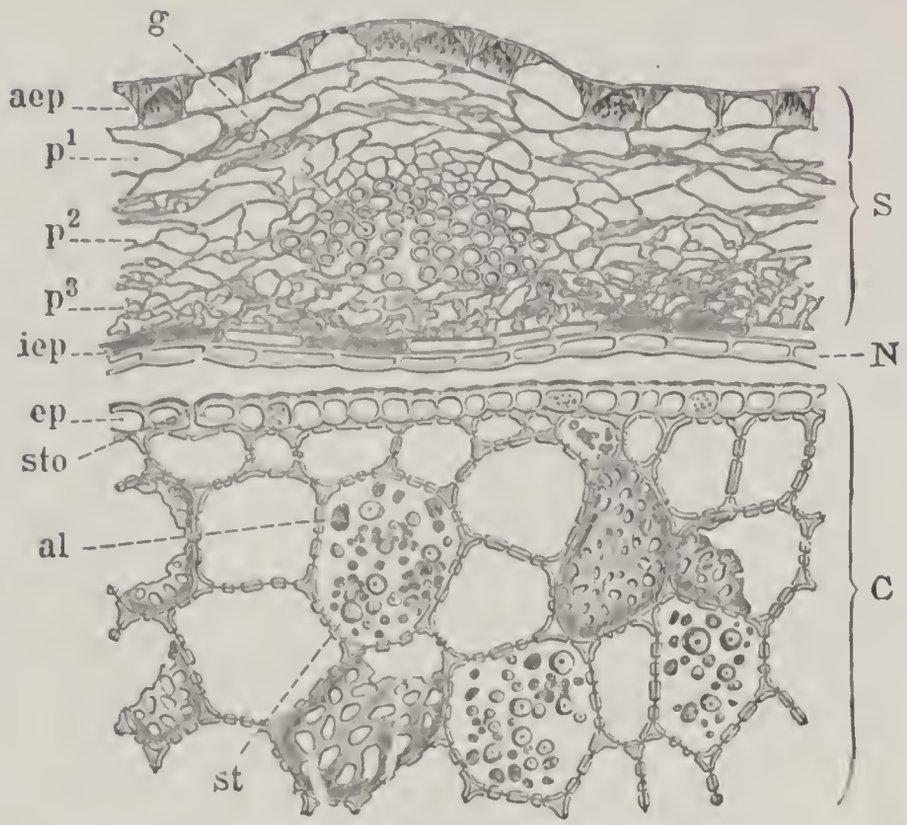


Fig. 214.—Peanut. Seed in cross section. *S* spermoderm: *aep* outer epiderm, p^1 subepiderm, p^2, p^3 spongy parenchyma, *iep* inner epiderm, *g* fibro-vascular bundle of raphe. *N* endosperm. *C* cotyledon: *ep* outer epiderm with *sto* stoma, *st* starch grains, *al* aleurone grains. ×160. (A.L.W.)

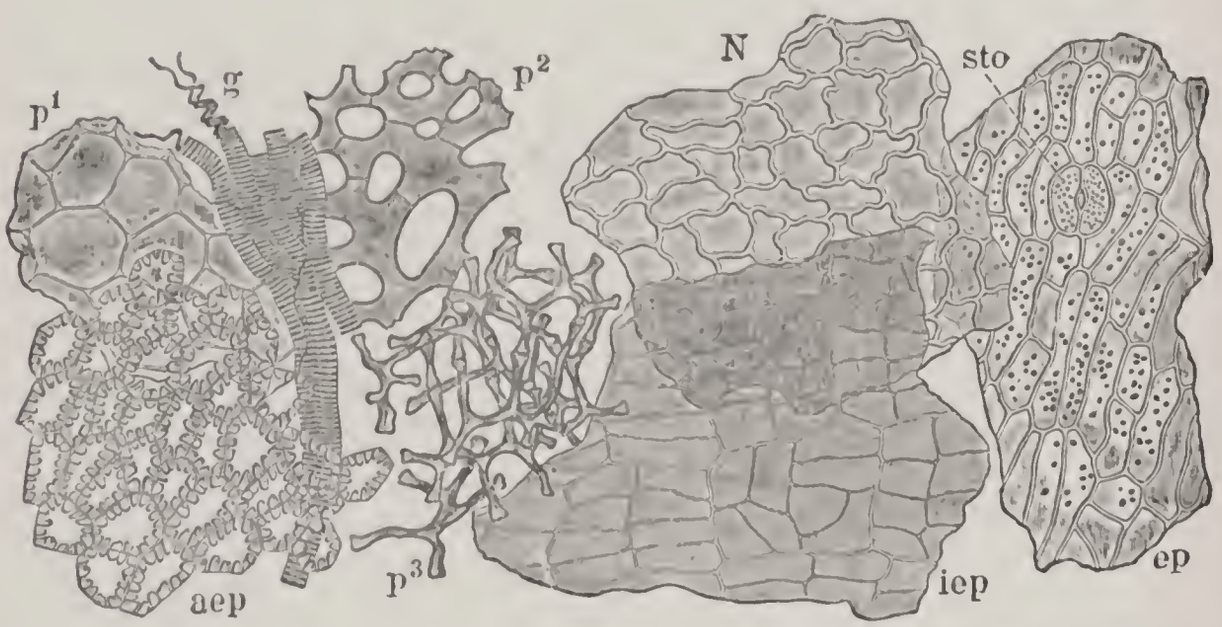


Fig. 215.—Peanut. Elements of seed in surface view. Spermoderm: *aep* outer epiderm, p^1 subepiderm, p^2, p^3 spongy parenchyma, *g* fibro-vascular bundle, *iep* inner epiderm. *N* endosperm. *ep* outer epiderm of cotyledon with *sto* stoma. ×160. (A.L.W.)

etc., thick- and thin-walled; outer epiderm of spermoderm low, up to 25 μ, and broad, up to 50 μ, porous, with broad lumen; subepiderm of

polygonal cells; inner parenchyma with narrow branches; endosperm of single layer; cotyledons with epiderms of tangentially elongated cells and stomata; mesophyl cells with thick, porous walls, containing globular starch grains and aleurone grains both up to 15 μ.

CHEMICAL COMPOSITION.—Although no extensive series of analyses of peanuts and peanut oils of known purity and widely distributed source is available, reliable data are at hand on the composition of the products and by-products showing the value of the peanut kernel, oil, and butter for human food and of the cake and hay for cattle food, also the nutritive worthlessness of peanut shells. Ash analyses of these are of interest to the agriculturist and nutritionist alike.

Shelled Peanuts.—The figures in the table below, showing the percentages of shells in the whole nut and the composition of the shelled nut or kernel, are on the authority of Dietrich, Hesse, and Greitherr,[1] Brown,[2] White,[3] Kilgore,[4] and Woods and Merrill:[5]

Composition of Shelled Peanuts

	Shells *	Water	Protein	Fat	N-f.ext.	Fiber	Ash
	%	%	%	%	%	%	%
Dietrich, Hesse and Greitherr:							
Bombay	.....	7.71	31.12	46.56	9.39	2.16	3.06
Congo	.....	5.01	26.62	50.22	14.09	1.47	2.59
Rufisque	.....	4.59	28.37	50.08	13.37	1.18	2.41
Brown:							
Tennessee 1888	.....	3.87	27.54	47.44	16.56	2.28	2.31
Tennessee 1889	.....	4.86	25.75	46.24	18.36	2.40	2.39
White:							
Spanish	22	13.15	27.95	35.77	17.73	3.04	2.36
Georgia	27	12.85	26.57	37.59	19.04	2.05	1.90
Kilgore	28.8	4.9	29.1	48.8	15.3		1.9
Woods and Merrill:							
Fresh nuts	28.0	6.0	28.1	45.7	17.8		2.4
Roasted nuts	32.6	1.6	30.5	49.2	16.2		2.5

* In whole nut.

Owing to the importance of the peanut in Texas agriculture, Fraps[6]

[1] Landw. Z. Cassel 1886, 654; König: Mensch. Nahr.-Genussm. 1903, **1**, 614.
[2] Tennessee Agr. Exp. Sta. 1891, Bul. **4**, II, 55.
[3] Georgia Agr. Exp. Sta. 1891, Bul. **13**.
[4] North Carolina Agr. Exp. Sta. 1893, Bul. **90B**, 10.
[5] Maine Agr. Exp. Sta. 1899, Bul. **54**, 79.
[6] Texas Agr. Exp. Sta. 1917, Bul. **222**.

has written a special bulletin on the composition of peanuts and peanut by-products, including peanut hay (see Forage Legumes), from which the limits and averages in the table below are taken:

Composition of Peanuts and By-products (Fraps)

	Samples	Water	Protein	Fat	N-f.ext.	Fiber	Ash
		%	%	%	%	%	%
Kernels:	63						
Min.	.....	3.49	28.26	44.99	6.02	2.06	1.87
Max.	.....	6.48	35.25	51.64	14.25	4.26	2.80
Aver.	.....	**5.01**	**32.06**	**48.73**	**9.48**	**2.44**	**2.28**
Shells:	58						
Min.	.....	6.16	4.53	0.21	10.03	47.39	2.08
Max.	.....	9.46	9.85	3.46	30.72	71.96	12.09
Aver.	.....	**7.48**	**6.76**	**1.10**	**19.64**	**60.83**	**4.19**
Whole nuts:	57						
Min.	.....	4.26	21.29	31.98	9.15	14.45	1.99
Max.	.....	6.96	28.40	40.18	15.50	23.93	4.95
Aver.	.....	**5.65**	**25.54**	**36.63**	**12.07**	**17.34**	**2.77**
Whole nuts, pressed:	56						
Min.	.....	5.00	16.25	6.79	16.20	17.50	3.00
Max.	.....	11.45	41.44	15.05	26.61	26.24	18.82
Aver.	.....	**7.98**	**35.49**	**9.03**	**21.16**	**21.94**	**4.48**
Cake, high grade:	9						
Min.	.....	4.11	41.94	6.93	17.67	4.49	4.04
Max.	.....	7.67	59.37	21.88	24.31	8.34	8.25
Aver.	.....	**6.08**	**49.50**	**11.38**	**22.07**	**5.96**	**5.01**
Cake, medium grade:	12						
Min.	.....	5.35	39.08	7.92	16.08	9.30	3.89
Max.	.....	8.14	47.00	11.05	26.40	18.74	7.55
Aver.	.....	**6.22**	**44.91**	**8.84**	**23.05**	**12.08**	**4.83**

Fuller [1] in the definitions and standards of the Texas Feed Control Service gives the limits for three grades of peanut meal or ground cake as follows: (1) not less than 48 per cent of protein and 7 per cent of fat and not more than 9 per cent of fiber, (2) not less than 45 per cent of protein and 6 per cent of fat and not more than 10 per cent of fiber, and (3) not less than 43 per cent of protein and 6 per cent of fat and not more than 12 per cent of fiber; also two grades of whole pressed peanuts ground or unground as follows: (1) not less than 36 per cent of protein and not more than 22 per cent of fiber, and (2) not less than 34 per cent of protein and not more than 24 per cent of fiber.

[1] Ibid. 1929, Bul. **404.**

Peanut Butter.—Analyses by Winton [1] of two brands, I made in Philadelphia and II in New Haven, Conn., follow:

Composition of Peanut Butter (Winton)

	I	II
	%	%
Water	2.10	1.98
Protein	28.66	29.94
Fat	46.41	46.68
Starch	6.15	5.58
Sugars, dextrins, etc.	6.13	5.63
Fiber	2.30	2.10
Salt	3.23	4.95
Ash other than salt	0.80	1.08
Undetermined (by difference)	4.22	2.06
	100.00	100.00

Both products, as claimed, evidently consisted solely of ground roasted peanuts and salt. The nearly equal percentages of starch and soluble carbohydrates are noteworthy.

Peanut Cake and the ground cake known as **Peanut Meal** vary in composition according to the composition of the peanuts and the degree of extraction as shown by Fraps analyses summarized above. Böhmer [2] found a range of from 42.23 to 50.23 per cent in protein and of 4.44 to 20.30 per cent in fat.

Peanut Skins.—Analyses by Füchs [3] of the inner red skin (spermoderm and perisperm) of the peanut, removed before pressing, show as high as 17 per cent of protein and 18 per cent of fat. Evidently shriveled and damaged kernels are included.

Peanut Shells.—Analyses, on the water-free basis, by White [4] of the shells of Spanish and Georgia peanuts, containing respectively 19.20 and 20.62 per cent of water, are shown below.

Proteins.—Ritthausen,[5] who isolated a *globulin*, is the only author mentioned by Osborne [6] as having studied the proteins prior to 1912.

[1] Connecticut Agr. Exp. Sta. Rep. 1899, p. 138.
[2] Kraftfuttermittel. Berlin, 1903, p. 521.
[3] Chem. Z. 1911, **35**, 358.
[4] Loc. cit.
[5] Pflüger's Arch. 1880, **21**, 81.
[6] Veg. Proteins. New York, 1912, p. 78.

Composition of Peanut Shells (White)

(Results in percentages of dry matter)

	Shell: *	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Spanish	22	7.19	2.08	14.32	71.78	4.63
Georgia	27	4.99	2.12	10.59	79.30	3.00

* In whole nut.

Lichnikov[1] extracted peanuts with water, 70 per cent alcohol, 10 per cent sodium chloride, and 0.25 per cent potassium hydroxide and isolated from the extracts proteins which he denominated *albumin*, *glutin*, and *globulin*. Out of the 9.10 per cent of nitrogen in the nuts, 8.74 per cent was found to be in the form of proteins. From glutin and globulin, after hydrolysis, he separated arginine, lysine, and histidine. As the original is in the Russian language, further details are lacking.

Johns and Jones [2] describe in detail the preparation of two globulins, *arachin* and *conarachin*. Arachin is precipitated from the 10 per cent brine solution by ammonium sulphate added to 20 per cent saturation. In the filtrate from the arachin the small amount of conarachin is prepared either by saturating completely with ammonium sulphate and dialyzing or by dialyzing directly.

Determinations by Jones and Horn [3] in finely ground, defatted shelled peanuts gave nitrogen 7.36 per cent, of which 86 per cent was soluble in 10 per cent salt solution. The oil-free meal contained arachin 25 and conarachin 8 per cent. Arachin does not coagulate in 10 per cent salt solution, even at boiling, and precipitates completely from the solution at 40 per cent saturation with ammonium sulphate, also by addition of trichloracetic acid, tannic acid, or tungstic acid; its specific rotation at 20° C. is −39.5°. Conarachin coagulates at 80° C. and precipitates practically completely from a 10 per cent salt solution on addition of ammonium sulphate to 85 per cent saturation; its specific rotation at 20° C. is −42.7. No appreciable amount of albumin, prolamine, or glutelin was detected.

The *Ultimate Composition* of the globulins described above follows.

Amino Acids of Peanut Globulins.—Basic amino acids were determined in both arachin and conarachin by Johns and Jones [4] employing

[1] Rez. Veg. Opyt. Lab. Rab. 1913, **9**, 378; Exp. Sta. Rec. **35**, 712.

[2] J. Biol. Chem. 1916, **28**, 77.

[3] J. Agr. Res. 1930, **40**, 673.

[4] Ibid. 1917, **30**, 33; 1918, **36**, 491.

	Ritthausen Globulin	Johns and Jones	
		Arachin	Conarachin
	%	%	%
Carbon	51.41	52.15	51.17
Hydrogen	6.74	6.93	6.87
Nitrogen	18.25	18.29	18.29
Sulphur	0.56	0.40	1.09
Oxygen	23.04	22.23	22.58
	100.00	100.00	100.00

Van Slyke's and Kossel and Kutscher's methods with agreeing results. Other amino acids were determined in arachin after hydrolysis.

Amino Acids of Peanut Globulins (Johns and Jones)

	Arachin	Conarachin
	%	%
Glycocoll	0.00	
Alanine	4.11	
Valine	1.13	
Leucine	3.88	
Cystine	0.85	0.86
Aspartic acid	5.25	
Glutamic acid	16.69	
Tyrosine	5.50	
Phenylalanine	2.60	
Proline	1.37	
Tryptophane	present	present
Arginine	13.51	14.60
Lysine	4.98	6.04
Histidine	1.88	1.83
Ammonia	2.03	1.90
	63.78	

Jones, Gersdorff, and Moeller [1] obtained the following figures for cystine and tryptophane.

Nitrogen Distribution in Peanut Proteins.—Van Slyke's method has

[1] Ibid. 1924, **62**, 183.

	Total globulin	Arachin	Conarachin	Albumin
	%	%	%	%
Cystine	1.42	1.08	3.00	1.47
Tryptophane	1.00	0.88	2.13	2.33

been applied by Johns and Jones [1] to arachin and conarachin, and by Dowell and Menaul [2] to the protein matter obtained by extracting the defatted ground kernel with dilute alkali and precipitating with acetic acid. Nollau[3] treated the ground peanut directly instead of the separated protein matter.

	Johns and Jones		Dowell and Menaul	Nollau
	Arachin	Conarachin	"Protein"	
	%	%	%	%
Humin N adsorbed by lime	0.57	0.65	1.2	4.36
Humin N in amyl alcohol extract	0.43	0.13		
Cystine N	0.74	0.75	0.77	0.81
Arginine N	23.77	25.78	17.57	20.82
Lysine N	5.22	6.35	6.22	5.31
Histidine N	2.78	2.72	1.88	6.13
Amino N of filtrate	53.30	50.23	61.25	52.36
Non-amino N of filtrate	1.65	1.94	1.67	1.40
Amide N	11.81	11.08	11.48	10.93
	100.27	99.63	102.04	102.12

Oil.—Lewkowitsch [4] states that only nuts imported in the shell are suited for the manufacture of edible oil, since the shelled nut deteriorates during shipment.

In Europe, notably in Marseilles, according to H. S. Bailey,[5] peanut oil is almost invariably expressed from shelled nuts, the shelling being commonly done in the country of origin. The cold expressed oil from nuts shelled at the mill is of edible grade without refining. The second

[1] Ibid. 1917, **30**, 33.
[2] Ibid. 1921, **46**, 437.
[3] Ibid. 1915, **21**, 611.
[4] Tech. Anal. Oils, etc. London, 1914, **2**, 297.
[5] U. S. Dept. Agr. Yearbook 1916, Separate **691**.

and third pressing yield oil of inferior quality. Bailey further states that in the United States both shelled and unshelled nuts are pressed, the Spanish variety being best suited for the purpose. The other varieties commonly grown, namely, Virginia Bunch, Virginia Runner, and African, contain smaller amounts of oil.

The *Physical and Chemical Values* of the samples used by Jamieson, Baughman, and Brauns[1] in determining the constituent fatty acids follow:

Values of Peanut Oil (Jamieson, Baughman, and Brauns)

	Spanish type peanuts	Virginia type peanuts
Specific gravity 25°/25°	0.9148	0.9136
Saponification number	188.2	187.8
Iodine number (Hanus)	90.1	94.8
Reichert-Meissl number	0.27	0.21
Polenske number	0.12	0.29
Acetyl number	8.7	9.50
Saturated acids (determined)	21.4%	17.4%
Saturated acids, iodine number	4.8	7.1
Unsaturated acids (determined)	73.4%	77.7%
Saturated acids (corrected)	20.6%	16.4%
Unsaturated acids (corrected)	74.6%	78.7%
Unsaturated acids, iodine number	121.8	118.2
Acid number	0.12	0.03
Unsaponifiable matter	0.22%	0.27%

The following table of maximum and minimum values has been compiled from published figures, being for the most part as given by Tolman and Munson:[2]

Values of Peanut Oil

	Sp. gr. 15.5° C.	Refractive index 15.5° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, m. pt.	Fatty acids, titer	Fatty acids, free
						° C.	° C.	%
Min.	0.911	1.4707	44	186	83	26.0	23	0.24
Max.	0.926	1.4731	67	198	105	36.4	32	13.51

[1] J. Am. Chem. Soc. 1921, **43**, 1372.

[2] U. S. Dept. Agr., Bur. Chem. 1903, Bul. **77**, 34.

Merrill [1] has shown that the oils obtained from raw and roasted peanuts have practically the same composition, the results being as follows:

	Sp. gr. 15.5° C.	Ref. ind. 25° C.	Iodine No.
Raw	0.9190	1.4683	92.51
Roasted	0.9196	1.4679	92.37

Composition of Peanut Oil.—From the data compiled by Jamieson, Baughman, and Brauns [2] it appears that the different fatty acids were first found in peanut oil by the following chemists: palmitic acid by Caldwell,[3] arachidic acid by Goessmann,[4] lignoceric acid by Kreiling,[5] and linolic acid by Hazura and Grüssner.[6] The presence of hypogæic acid, claimed by several chemists, has been abundantly disproved.

Quantitative determinations by Heiduschka and Felser [7] of the constituents of a single sample and by Jamieson, Baughman, and Brauns [2] of one sample each of oil from Spanish and Virginia type peanuts follow:

Composition of Peanut Oil

	Heiduschka and Felser	Jamieson, Baughman, and Brauns	
		Spanish	Virginia
	%	%	%
Glycerides of:			
Lignoceric acid	1.9	3.1	2.6
Arachidic acid	2.3	4.0	3.3
Stearic acid	4.5	6.2	4.9
Palmitic acid	4.0	8.2	6.3
Oleic acid	79.9	52.9	60.6
Linolic acid	7.4	24.7	21.6
Unsaponifiable matter	....	0.2	0.3
	100.0	99.3	99.6

[1] Maine Agr. Exp. Sta. 1900, Bul. 65.
[2] Loc. cit.
[3] Ann. 1857, 101, 97.
[4] Ibid. 1854, 89, 1.
[5] Ber. 1888, 21, 880.
[6] Monatsh. Chem. 1890, 10, 242.
[7] Z. Unters. Nahr.-Genussm. 1919, 38, 242.

Holde and Godbole [1] separated from East Indian peanut oil *hexacosanic acid* ($C_{26}H_{52}O_2$) and lignoceric acid containing hexacosanic acid as an impurity. The hexacosanic acid had a molecular weight of 391.5 (calculated 396) and a melting point of 77.5 to 80° C. The content in the oil was estimated to be 0.1 to 0.2 per cent.

Carbohydrates.—The general analyses show that less than 20 per cent of the shelled peanut consists of carbohydrates other than fiber. Analyses of peanut butter show that the amount of starch about equals that of soluble carbohydrates, the sum of the two lacking but 2 to 4 per cent of the total percentage of nitrogen-free extract.

As the peanut is unique among economic seeds in that the fruit ripens underground and partakes of certain root characters (see Microscopic Structure), further studies of the carbohydrates may have physiological significance.

Mineral Constituents.—Ash analyses were made of single samples of the kernel and shells by Brown [2] and of 22 samples each of kernels and shells by Fraps.[3] The results as given by Fraps being in terms of percentages of the kernel, they have been recalculated for comparison with Brown's results, assuming the total ash to be 2.28 and 4.19 per cent, which are the averages of 63 and 68 determinations respectively made by the same author. Attention is directed to the exceptionally low percentage of magnesia and high percentage of sulphuric acid found by Brown in the kernel. Fraps' figure for magnesia is the average of 16 determinations agreeing within narrow range made on as many samples and is doubtless correct. König [4] gives an analysis, without reference to the source, agreeing with that of Brown except that each result differs by a few hundredths of 1 per cent.

Analysis of Peanut Ash

	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Sand	Undet.
	%	%	%	%	%	%	%	%	%
Kernels:									
Brown	39.85	2.85	4.11	1.83	38.90	10.40	0.20	....	1.86
Fraps	35.96	....	4.78	14.91	35.21	....	....	3.86	5.28
Shells:									
Brown	31.78	7.85	27.01	12.60	5.63	8.89	4.13	....	2.11
Fraps	27.68	....	7.40	5.97	3.57	....	....	42.73	12.65

[1] Z. deut. Oel, Fett Ind. 1926, **46**, 129, 145, 163, 179.
[2] Loc. cit. [3] Loc. cit.
[4] Chem. mensch. Nahr.-Genussm. Berlin, 1920, **2**, 874.

Minor Mineral Constituents. *Iron.*—Peeled 20 mg. per kilo, fresh basis (Sherman).[1]

Manganese.—Kernel 8.51, shell 15.40 mg. per kilo, dry basis (Quartaroli).[2]

Copper.—Seed 6.8 mg. per kilo, dry basis (Hirano and Mikumo).[3] Kernel 20.4, shell 12.2 mg. per kilo, dry basis (Quartaroli).[2]

Zinc.—Whole seed 16 mg. per kilo, fresh basis (Bertrand and Benzon).[4]

SOY BEAN

Glycine Soja Sieb. et Zucc. = *G. hispida* Maxim = *Soja hispida* Moench = Dolichos Soja L.

Fr. Soja. It. Soia. Ger. Sojabohne.

A native of the Far East, the soy bean has been cultivated since the dawn of civilization in China and Japan, where the seeds furnish millions of human beings with food. From the seeds are prepared soy cheeses (tofu, natto, miso), soy milk, and soy sauce, the latter being used in chop suey. Because of the absence of starch in many varieties soy bean flour has come into use in the Occident as a diabetic food. Soy bean oil is of growing industrial importance.

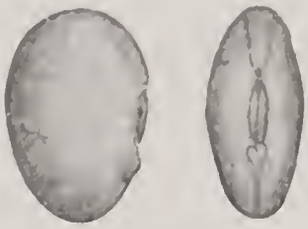


Fig. 216.

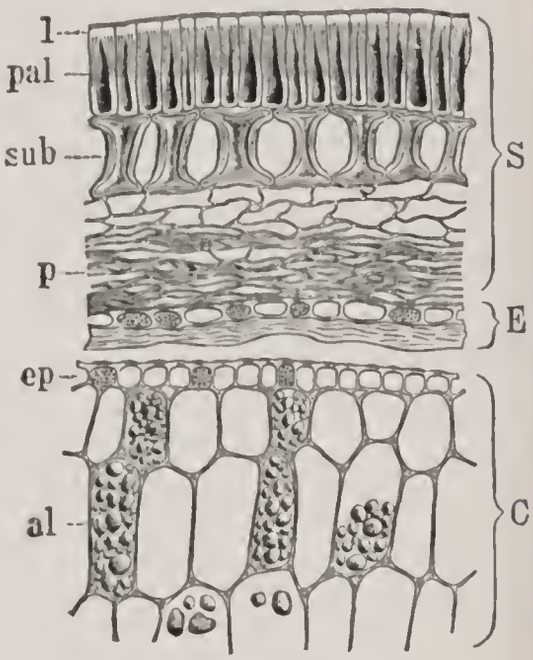


Fig. 217.

Fig. 216.—Soy Bean. Seed. ×2. (A.L.W.)

Fig. 217.—Soy Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *l* light line, *sub* subepiderm, *p* parenchyma. *E* endosperm. *C* cotyledon: *ep* outer epiderm, *al* aleurone grains. ×160. (A.L.W.)

As a forage and soiling crop the plant is grown to some extent in the United States. (See Part III, Forage Plants.)

MACROSCOPIC STRUCTURE.—The short hairy *pods* usually contain two or three seeds. Unlike the bean the ovoid (up to 12 mm.) or nearly spherical (less than 10 mm.) *seed* (Fig. 216) is not kidney-shaped

[1] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. 185.

[2] Ann. chim. appl. 1928, **18**, 47.

[3] J. Pharm. Soc. Japan, 1925, **525**, 992.

[4] Bul. soc. hyg. aliment. 1928, **16**, 457.

but evenly rounded. Buff-seeded varieties are best known in the United States, but there is a wide range in color in the numerous varieties grown in the Orient. Solid colors—yellow, buff, green, red, brown, and black—are more common than combinations giving a mottled or spotted effect. The hilum is distinct (3 to 4 mm.) with a well-marked margin and slit, but there is little evidence of a caruncle or hilum cushion, hence the absence of a strongly contrasting pure white patch. Strophiole and micropyle are evident but not conspicuous. The form of the radicle shows through the spermoderm.

MICROSCOPIC STRUCTURE (Fig. 217).—From common shell legumes the soy bean is distinguished by the relatively high subepidermal cells, the presence of a distinct endosperm, and usually the absence of starch in the cotyledon.

Spermoderm (*S*).—The layers are (1) *palisade cells* (*pal*), up to 60 μ high and 20 μ broad, with light line, in colored beans containing a pigment, (2) *subepiderm* (*sub*) of strikingly spool-shaped cells up to 75 μ high and 40 μ broad, and (3) *spongy parenchyma* (*p*), compressed in the inner portion.

The following table by M. Kondo [1] shows the original color of the contents of the *palisade cells* and the microreactions with a series of reagents:

	Black seed from Japan	Black seed from China	Green seed from Japan	Dark wine-red seed from Japan
Original color	Blue	Brown	Clive green	Yellow-brown
Color with:				
Sulphuric acid	Cherry red	Dark red	No change	No change
Acetic acid	Reddish brown	Dark red	Bright yellow	No change
Potassium hydroxide	Brown	Brown		
Chloral hydrate	Cherry red	Reddish brown	Bright yellow	No change
Ferric chloride	.....	.....	No change	Dark brown
Iodine in potassium iodide	.....	.....	Yellow	
Alcohol	.....	.....	Yellow	
Methyl green	.....	.....	Dark green	
Eosin	.....	.....	Red	

He concludes that the blue color of the black Japan seed is an anthocyan, that the brown color of the black Chinese seed may be a tannin-containing anthocyan, while the olive green color of the Japan green

[1] Z. Unters. Nahr.-Genussm. 1913, **25**, 1.

seed is chlorophyl and that the yellow-brown color of the dark wine-red Japan seed is probably tannin. The palisade cells of yellow seeds contain no pigment, the color being located in the cotyledon.

In the hilum region the *spongy parenchyma* is very loose and thick-walled.

Hilum Cushion.—Absent or only traces at the edges.

Endosperm (*E*).—A single layer of typical *aleurone cells* and a band of *compressed cells* are evident in cross section. In surface view the outer cells are polygonal, up to 50 μ in diameter, and show minute aleurone grains and formless contents.

Embryo.—The cotyledons (*C*) show several characteristics: (1) the much-elongated *palisade cells* on the inner side and the somewhat elongated cells on the outer side, (2) the absence of *starch* in many varieties and (3) the presence of *oxalate crystals*.

M. Kondo [1] reports *palisade cells* up to 105 μ high. Well-marked palisade cells in cotyledons of economic leguminous seeds are unusual.

Oxalate crystals in the mesophyl were first brought to notice by Wallis.[2] They are best seen in cut sections examined with polarized light.

Special interest centers in the presence or absence of *starch*. Long since, Harz [3] and Hànausek [4] noted the presence of small amounts of starch in some specimens but since it usually was absent its occurrence has generally been considered as a sign of immaturity or insufficient ripening (ageing) after harvesting. Harz advanced this theory, and Wallis as late as July, 1913, accepted it. Kondo,[1] however, in his monograph on the anatomy of exotic leguminous seeds, published in January, 1913, expresses the opinion that in certain varieties it is always present. He found that the starch is present chiefly in the inner (about two-thirds) portion of the cotyledon. Furthermore its presence is independent of the color of the seed, as shown by the following results: In yellow seed from Japan, little starch, in yellow seed from China, none; in black seed from Japan much starch, in black seed from China, none; in green seed from Japan, very little, in green seed from China, none; in dark wine-red seed from Japan, very little, in brown seed from Japan, none.

Aleurone grains and *fat* are the chief constituents regardless of the occurrence of starch. The grains (*al*) are isodiametric or somewhat elongated, well rounded or somewhat angled, varying in size in species

[1] Loc. cit.
[2] Pharm. Jour. and Pharm. July 26, 1913.
[3] Z. allg. oesterr. Apoth.-Ver. 1885, p. 40.
[4] Ibid. 1884, p. 474.

examined by us up to over 20 μ; Tschirch and Oesterle give 23 μ as the maximum. According to Kondo [1] they are largest in Chinese varieties. In yellow and black Chinese seeds he found in both cases the maximum to be 16 μ, in yellow and black Japanese seeds respectively 7 and 8 μ.

CHIEF STRUCTURAL CHARACTERS.—Seeds well rounded (not kidney-shaped), hilum cushion absent.

Palisade cells up to 60 μ, high and 20 μ broad, with flat ends; subepidermal cells spool-shaped, up to 75 μ high and 40 μ broad; endosperm present; aleurone grains and fat in cotyledons; starch usually absent but in some varieties present in small or even large amount; cotyledons with palisade cells.

CHEMICAL COMPOSITION.—A summary of 8 analyses of the whole beans made in American experiment stations, compiled by Jenkins and Winton,[2] and of 19 analyses by Street and Bailey,[3] reduced to 10 per cent water content, follow:

COMPOSITION OF SOY BEANS

	Samples	Water	Protein (N × 6.25)	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Compiled:	8						
Min.	.....	5.85	26.25	12.27	26.17	2.45	3.07
Max.	.....	19.27	40.22	19.01	32.84	6.13	5.40
Aver.	.....	**10.80**	**33.98**	**16.85**	**28.89**	**4.79**	**4.69**
Street and Bailey:	19						
Min.	.....	10.00	33.15	12.72	23.58	3.57	4.67
Max.	.....	10.00	40.99	17.07	29.59	5.87	7.77
Aver.	.....	**10.00**	**38.29**	**14.89**	**26.64**	**4.64**	**5.54**

Analyses of over 500 samples grown at Arlington, Va., reported by Piper and Morse,[4] show a range of protein from 31 to 46.9 and of fat from 11.8 to 22.5 per cent. The authors state that about 9 per cent of oil is secured by the hydraulic and 4 to 6 per cent by the expeller method, the cake varying accordingly.

Changes in Composition During Growth.—Tsukunaga and Nishino [5] have shown that calculated to the dry basis the content of protein and

[1] Loc. cit.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11.**

[3] J. Ind. Eng. Chem. 1915, **7**, 853.

[4] U. S. Dept. Agr., 1916, Bul. **439.**

[5] J. Sci. Agr. Soc. Japan 1930, **322**, 16.

fat increase during the ripening, whereas that of nitrogen-free extract, fiber, and ash decrease. The iodine number of the fat reached the maximum of 137.5 per cent about 8 weeks after blooming.

Soy Bean Cake, Meal, and Flour.—The enormous quantities of cake obtained in Manchuria from the manufacture of soy oil appear to be consumed largely in the Orient or Europe. It varies in composition with the variety and process of extraction. A typical analysis of the ground cake, known as meal, recorded by Lindsey, Smith, and Beals,[1] appears in the table below.

Soy bean flour, consisting of the ground bean from which the hulls have been separated, has decided value as a diabetic food because of its practical freedom from starch, as noted by Winton,[2] Street,[3] and others. Its use as an invalid food is advocated by Ruräh.[4] Analyses of 7 samples of the flour are given by Street and Bailey [5] and summarized below:

Composition of Soy Bean Cake and Flour

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Meal (ground cake):							
Lindsey, Smith, and Beals	1	8.0	41.6	8.6	31.6	4.8	5.4
Flour:							
Street and Bailey:	7						
Min.	.....	3.0	39.9	18.2	22.4	1.9	4.1
Max.	.....	7.8	45.7	21.4	25.8	5.4	5.1
Aver.	.....	5.1	42.5	19.9	24.3	3.7	4.5

Proteins.—A globulin, *glycinin*, so named by Osborne and Campbell,[6] is the principal protein. The greater part of this "salt-soluble protein" goes into the water solution of the freshly ground seed, but separates after a time when the extract becomes acid. Addition of a small amount of acid hastens the precipitation. According to Osborne and Campbell a small amount of a more soluble globulin, probably identical with the *phascolin* of other legumes, and about 1.5 per cent of an albumin, *legumelin*, are also present.

[1] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.
[2] Connecticut Agr. Exp. Sta. Rep. 1906, p. 153.
[3] Ibid. 1912, p. 107.
[4] Arch. Ped. 1909.
[5] Loc. cit.
[6] J. Am. Chem. Soc. 1898, **20**, 419.

Muramatsu [1] extracted successively from dry ground soy beans from northern Japan the following percentages of the total protein with the solvents named: with water 65.2 to 90, with salt solution 3.97 to 6.40, and with alkali 1.64 to 3.49 per cent, the residual nitrogen calculated as protein being 3.51 to 24.91 per cent. The total globulin consisted of 78.5 per cent of glycinin and 21.5 per cent of phaseolin, the total albumin of 78.5 per cent of legumelin and 21.21 per cent of soylegumelin. He proposes the factor 5.82 for calculating the protein from the nitrogen.

Tadokoro and Toshimura[2] designate the proteins as extracted by them with water *glycinin A* and *legumelin*, with 10 per cent salt solution *glycinin B*, and with 0.2 per cent sodium hydroxide solution *glutelin*.

The *Ultimate Composition* as determined by Osborne and Campbell [3] of glycinin, legumelin, and proteose, and by Muramatsu [1] of soylegumelin follows:

	Glycinin	Legumelin	Soylegumelin	Proteose
	%	%	%	%
Carbon	52.12	53.06	52.98	48.76
Hydrogen	6.93	6.94	6.79	6.28
Nitrogen	17.53	16.14	15.14	16.14
Sulphur	0.79	1.17	0.29	
Oxygen	22.63	22.69	24.80	28.82
	100.00	100.00	100.00	100.00

Amino Acids of Soy Proteins.—Glycinin was hydrolyzed by Osborne and Clapp [4] and the percentages of the products in the water- and ash-free material determined as shown in the table on the following page.

Onuki,[5] following Dakin's butyric acid method, isolated from 100 grams of dry protein matter 5.47 grams of β-hydroxyglutamic acid, but was unable to determine from which individual protein it was derived and the full amount present.

Jones, Gersdorff, and Moeller [6] obtained from glycinin the following: cystine 1.12 and tryptophane 1.66 per cent.

Tadokoro and Toshimura [7] found that the free amide nitrogen is greater in glycinin than in the glutelin and greater in the glutelin than in legumelin. Glycinin yields by far the largest amount of humin,

[1] J. Tokyo Chem. Soc. 1920, **41**, 311.
[2] Hokkaido J. Agr. 1928, **20**, 355.
[3] Loc. cit.
[4] Am. J. Physiol. 1907, **19**, 468.
[5] J. Chem. Soc. Japan 1922, **43**, 737.
[6] J. Biol. Chem. 1924, **62**, 183.
[7] Loc. cit.

PRODUCTS OF HYDROLYSIS OF GLYCININ (OSBORNE AND CLAPP)

	%
Glycocoll	0.97
Alanine	.....
Valine	0.68
Leucine	8.45
Serine	.....
Aspartic acid	3.86
Glutamic acid	19.46
Tyrosine	1.86
Phenylalanine	3.83
Proline	3.78
Tryptophane	+
Arginine	5.12
Lysine	2.71
Histidine	1.39
Ammonia	2.56
	54.67

legumelin the largest amount of histidine, and the glutelin the largest amount of lysine. The isoelectric point is highest in glucinin, lowest in legumelin.

Nitrogen Distribution in Soy Beans.—The following results on nitrogen distribution by Nollau,[1] Hamilton, Uyei, Baker, and Grindley,[2] and Mashino and Nishimura [3] for the most part are concordant, considering the differences in the samples and the nature of the methods:

	Nollau	Hamilton et al.	M. and N.
	%	%	%
Humin N	3.69	2.87	6.14
Arginine N	15.52	15.70	15.55
Cystine N	1.52	1.46	1.74
Histidine N	2.60	5.60	7.03
Lysine N	7.02	6.18	6.08
Total basic or di-amino N	26.66	28.94	30.40
Mono-amino N	48.76	48.28	49.76
Non-amino N	7.12	10.95	5.19
Amide N	12.97	9.38	9.58
	99.20	100.53	101.07

[1] J. Biol. Chem. 1915, **21**, 611.
[2] J. Am. Chem. Soc. 1923, **45**, 815.
[3] J. Soc. Chem. Ind. Japan, 1927, **30**, 607.

Shita and Yanagigawa[1] obtained from soy bean meal: amide nitrogen 10.0, humin nitrogen 4.83, di-amino nitrogen 26.43, and mono-amino nitrogen 58.74 per cent.

Decomposition of soy bean proteins into amide and amino forms by hydrochloric acid, sulphuric acid, and sodium hydroxide of different concentrations has been studied by Mashino.[2]

Oil.—The commercial oil is largely used for technical purposes. Carefully refined oil is edible but its keeping qualities are poor.

Physical and Chemical Values. — Up to about the time of the World War when the soy bean and its products had not entered the world's commerce, only scattering data on its values and composition were available.

In 1912 Thompson and Morgan[3] extracted soy beans grown in Delaware with gasoline and with ether, the latter solvent yielding an average of 19.22 per cent of oil. The constants of the oil were as follows: specific gravity at 15.5° C. 0.9108 to 0.9235, aver. **0.9193**; saponification number 174.1 to 195.4, aver. **187.3**; and iodine number 114.0 to 139.0, aver. **129.7**. A composite sample had: Reichert-Meissl number 5.3, Hehner number 93.5, neutralization value 177.8, iodine number of unsaturated fatty acids 131.9, unsaturated fatty acids 84.7 per cent, saturated fatty acids 8.61 per cent, ether number 188.4, glycerol 10.29 per cent, and mean molecular weight 315.5.

In 1916 Washburn[4] carried out an extensive investigation on the oil content (ether extract) and the constants of the oil obtained by hydraulic pressure of 202 samples of beans grown in different states of the Union and in Canada. The average results for varieties represented by more than 2 samples, also the range in composition of all the analyses, follow on the next page.

Fellers[5] determined in 10 samples of oil the same constants as Washburn and in addition the acid number. The range in values was: specific gravity 0.922 to 0.926, refractive index at 25° C. 1.4720 to 1.4750, saponfication number 190.2 to 195.8, iodine number 123.2 to 132.3, and acid number 0.17 to 2.6. In 2 samples he reports the following additional values: Reichert-Meissl number 5.2 and 4.3, Hehner number 94.3 and 93.0, neutralization value 195.2 and 190.3, unsaturated fatty acids 85.7 and 84.9 per cent, saturated fatty acids 9.2 and 8.6 per cent, and ether number 190.1 and 187.2. The range in oil content of

[1] Rep. Imp. Ind. Res. Inst., Osaka, Japan, 1926, **7**, 1.
[2] J. Soc. Chem. Ind., Japan, 1926, **29**, 179, 248.
[3] Delaware Agr. Exp. Sta. Bul. **99**.
[4] N. Dakota Agr. Exp. Sta. Bul. **118**.
[5] J. Ind. Eng. Chem. 1921, **13**, 689.

Values of Soy Bean Oil (Washburn)

Variety	Samples	Fat (ether extract) in seed	Values of Pressed Oil			
			Sp. gr. 15.5° C.	Ref. ind. 25° C.	Sapon. No.	Iodine No.
		%				
Black Beauty (Ebony)	7	19.1	0.9255	1.4727	193.0	126.5
Ito San	19	19.4	0.9252	1.4732	193.4	131.2
Mammouth	5	20.8	0.9254	1.4732	194.1	128.5
Guelph	12	21.3	0.9251	1.4725	194.0	126.0
Haberlandt	8	21.1	0.9251	1.4733	192.6	129.2
Peking	7	19.6	0.9258	1.4737	193.4	132.6
Wilson	18	20.1	0.9258	1.4733	193.2	129.0
Holly Brook	8	19.5	0.9253	1.4735	193.9	127.8
Medium Yellow	5	21.2	0.9256	1.4737	194.1	130.2
Morse	4	22.4	0.9250	1.4735	192.8	133.2
Manchurian	33	22.1	0.9253	1.4728	193.0	126.6
Ogema	3	19.2	0.9266	1.4730	193.0	128.2
Quebec	4	17.9	0.9256	1.4737	192.7	131.2
Quebec	3	17.5	0.9250	1.4732	192.4	133.5
All varieties:						
Min.	.....	.....	0.9207	1.4710	190.1	115.5
Max.	.....	.....	0.9310	1.4750	197.4	141.9

26 samples of the seed, grown mostly in New Jersey, was 14.6 to 25.6, the average 18.3 per cent.

Composition of Soy Oil.—The percentages of glycerides given by Matthes and Dahle [1] have been shown by Baughman and Jamieson[2] to be incorrect. Keimatsu [3] found about 80 per cent of unsaturated and 12 per cent of saturated acids, which figures appear to be accurate, but he considers that half of the unsaturated acid is an isomer of linolic acid, 15 per cent is linolic acid, and 35 per cent is oleic acid.

Smith[4] and Baughman and Jamieson[2] agree within reasonable limits in their conclusion as to the proportion of saturated to unsaturated acids and percentages of linolenic, linolic, and oleic acids in the latter, but Smith does not give the percentages of saturated acids nor does Kaufmann.[5]

Grossfeld found erucic acid in about the same amount (1.73 to 2.34 per cent) as in linseed (which see).

[1] Arch. Pharm. 1911, **249**, 424.
[2] J. Am. Chem. Soc. 1922, **44**, 2947.
[3] Chem. Z. 1911, **35**, 939.
[4] J. Ind. Eng. Chem. 1922, **14**, 530.
[5] Allg. Öl-Fett. Ztg. 1930, **27**, 325.

Composition of Soy Oil

	Baughman and Jamieson	Smith	Kaufmann			
			Manchurian		American	
			Crude	Refined	Crude	Refined
	%	%	%	%	%	%
Glycerides of:						
Lignoceric acid	0.1					
Arachidic acid	0.7	9.3	15.1	15.7	15.0	14.7
Stearic acid	4.4					
Palmitic acid	6.8					
Oleic acid	33.4	26.5	21.1	25.7	24.5	24.6
Linolic acid	51.5	56.6	54.5	50.9	53.3	50.2
Linolenic acid	2.3	2.4	8.1	7.0	6.4	9.9
Unsaponifiable matter	0.6	.....	1.2	0.6	0.7	0.6
	99.8	94.8	100.0	99.9	99.9	100.0

Sterols.—Matthes and Dahle [1] separate by petroleum ether the unsaponifiable matter (0.7 per cent) into (1) 55 per cent of a crystalline portion and (2) 45 per cent of a soluble liquid portion. About 97 per cent of the crystalline portion is a levorotatory phytosterol, melting at 139° C., with one double linkage; the remainder is a phytosterol, melting at 169° C., with two double linkages, identical with the stigmasterol of Windaus and Hauth occurring in Calabar beans. The liquid portion consists of unsaturated oxygenated substances with the same ratio of carbon to hydrogen as in the phytosterol.

Carbohydrates.—Levallois [2] found in the soy bean as high as 11 per cent of galactan.

Borghesani [3] reports 3.86 to 2.86 per cent of pentosans, also methylpentosans, the ratio of pentosans to methylpentosans being 6.2 : 1.

According to Miyake,[4] pentosans and methylpentosans are distinctly skeletal constituents not used in germination unless other substances are exhausted and then methylpentosans are appropriated more than pentosans.

As noted under Microscopic Structure, starch, according to Harz,

[1] Arch. Pharm. 1911, **249**, 436.
[2] Compt. rend. 1878, **90**, 1293; 1881, **93**, 281.
[3] Staz. sper. agr. ital. 1907, **40**, 118; J. Landw. 1910, **58**, 77.
[4] J. Col. Agr. Tohoku Imp. Univ. Japan, 1913, **4**, 327.

does not occur in ripe and matured seeds, only in unripe or insufficiently matured seeds; Kondo, on the other hand, found that it is a normal constituent of certain varieties.

An analysis by Street and Bailey [1] of beans of the Hollybrook variety, containing 31.08 per cent of nitrogen-free extract and fiber, gave the following results:

Carbohydrates of Soy Bean (Street and Bailey)

	%
Galactan *	4.86
Pentosans	4.94
Organic acid †	1.44
Invert sugar	0.07
Sucrose	3.31
Raffinose	1.13
Starch	0.50
Cellulose	3.29
Undetermined hemicelluloses	0.04
Dextrin	3.14
Waxes, color, tannin, etc. (diff.)	8.60
	31.32
Galactan from raffinose	0.24
	31.08

* Includes 0.24 per cent from raffinose. † Calculated as citric.

Tanret [2] isolated *stachyose* from the soy bean.

Phosphorus-Organic Compounds.—*Lecithin* was found by Schulze [3] in the soy bean to the extent of 1.64 per cent, calculated to the dry matter.

Saponins.—A saponin ($C_{52}H_{80}O_{21}$) discovered by Sumiki,[4] as shown by hydrolysis, consisted of one molecule each of sapogenin, glucose, rhamnose, arabinose, and a fifth substance, probably an organic acid (mesoxalic). Sumiki later [5] prepared from the 70 per cent alcoholic solution of the free saponin, by neutralization with sodium hydroxide, the sodium salt which crystallizes as hexagonal plates. The toxicity of the saponin is low.

[1] Loc. cit.
[2] Compt. rend. 1912, **155**, 1526.
[3] Landw. Jahrb. Schweiz, 1892, **6**, 72.
[4] Bull. Agr. Chem. Soc. Japan 1929, **5**, 27.
[5] Ibid. 1930, **6**, 49.

Enzymes.—*Urease*, the enzyme-liberating ammonia from urea, first discovered by Musculus [1] in urine, later found in various molds, was shown by Takeuchi [2] to be present in especially large amount in the soy bean. He applied the principle to the manufacture of ammonium sulphate from urine. Takeuchi [3] also showed that urease does not act on uric acid, guanidine, arginine, creatine, and allantoin. The enzyme is readily prepared, as recommended by Jacoby and Sugga,[4] by extracting the defatted meal with water at 0° C., evaporating and drying at room temperature.

As shown by Hindmarsh,[5] varieties of soy beans as well as other legumes differ in their urease content, some containing less than half as much as others. Wagenaar [6] finds urease only in the embryo, chiefly in the outer epiderm of the cotyledon.

The *co-enzyme* also present in soy bean is believed by Onodera [7] to consist of two groups of components only one of which dialyzes. A solution which had lost its activity was again activated by the addition of a small amount of fresh urease. Germinating soy beans contain urease in greatly increased amount but no co-enzyme.

Zémplen [8] found urease in several other leguminous seeds but not in cereals. Fernandez and Pizarrosa [9] and Nemac [10] found it in various high-protein seeds and even in cereals.

Uricase.—This enzyme, also present in the soy bean, decomposes uric acid with the formation of allantoin. As shown by Fosse, Brunel, De Graeve, Thomas, and Sarazin [11] it may be destroyed without injury to the urease by maceration of the ground bean with water and after standing overnight in an icebox heating 30 minutes at 78° C. or by drying over calcium chloride and heating in sealed tubes 50 hours at 82° C.

Allantoinase is also uninjured by the foregoing treatment.

Mineral Constituents.—In the table below are the extreme results, recalculated, of analyses of soy beans grown in China, Austria, and

[1] Compt. rend. 1874, **78**, 132.
[2] J. Col. Agr. Tokyo, 1909, **1**, 1414.
[3] Chem. Ztg. 1911, **35**, 408.
[4] Biochem. Z. 1915, **69**, 116.
[5] Australian J. Exptl. Biol. Med. Sci. 1926, **3**, 167.
[6] Pharm. Weekbl. 1924, **61**, 535.
[7] Biochem. J. 1915, **9**, 575.
[8] Z. physiol. Chem. 1912, **79**, 229.
[9] An. soc. españ. fis. quim. 1917, **15**, 209.
[10] Biochem. Z. 1918, **91**, 126.
[11] Compt. rend. 1930, **191**, 1025.

France, reported by Pellet,[1] also the results of a single analysis reported by Schwackhöfer [2] and of one, recalculated, reported by Haskins.[3]

Analyses of Soy Bean Ash

	Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Pellet:										
Min.....	4.66	45.4	1.6†	4.5	6.5	.....	30.5	1.4	1.2	0.8
Max.....	5.10	46.9	4.9†	9.3	8.6	.....	32.3	4.8	1.2	0.8
Schwackhöfer	2.87	44.6	1.0	5.3	8.9	trace	36.9	2.7	trace	0.3
Haskins....	2.86	44.1	1.1	5.9	8.7	.....	36.4	2.8	.....	0.4

* In whole beans. † Includes Fe_2O_3 and Al_2O_3.

Minor Mineral Constituents. *Iron.*—In 10 varieties 57 to 88, aver. **74** mg. per kilo, dry basis (McHargue).[4]

Manganese.—In the 10 varieties tested for iron, 21 to 41, aver. **28** mg. per kilo, dry basis (McHargue).[4] Bean 12.6 mg. per kilo, air-dry basis (Quartaroli).[5]

Copper.—Bean 12 mg. per kilo, dry basis (McHargue);[6] 21.75 mg. per kilo, air-dry basis (Quartaroli);[5] 9 mg. per kilo, air-dry basis (Guerithault);[7] 15.9 mg. per kilo, dry basis (Hirano and Mikumo).[8]

Zinc.—Bean 18.4 mg. per kilo, dry basis (McHargue).[6] Dry bean 0.12 mg. per kilo, air-dry basis (Birckner).[9] Bean 20 mg. per kilo, air-dry basis (Bertrand and Benzon).[10]

Iodine.—None (Winterstein).[11]

[1] Ber. 1880, **13**, 1483.
[2] Landw. Vers.-Stat. 1877, **20**, 265.
[3] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.
[4] J. Agr. Res. 1923, **23**, 395.
[5] Ann. chim. appl. 1928, **18**, 47.
[6] J. Agr. Res. 1925, **30**, 193.
[7] Compt. rend. 1920, **171**, 196.
[8] J. Pharm. Soc. Japan 1925, **525**, 992.
[9] J. Biol. Chem. 1919, **38**, 191.
[10] Bul. soc. hyg. aliment. 1928, **16**, 457.
[11] Z. physiol. Chem. 1918, **104**, 54.

SEEDS OF THE FLAX FAMILY

(*Linaceæ*)

Only one seed, namely, linseed known also as flax seed, is here described.

LINSEED

Linum usitatissimum L.

Fr. Lin. Sp. Linaza. It. Lino. Ger. Leinsamen.

The cultivation of common or annual flax for fiber extends back to early Assyrian and Egyptian civilization. Before its introduction into Europe the lake dwellers and inhabitants of northern Italy depended on perennial flax (*L. angustifolium*) for flax fiber.

Although the same species yields fiber and oil seed, the latter must reach maturity before it can be used for oil production, whereas the fiber is in the best condition at an earlier stage. It follows that the cultivation of the crop for the two purposes is entirely distinct.

The seed is grown for oil in Russia, India, northern Africa, Argentina, Canada, and the United States. Because of its drying properties the oil is indispensable for paint and kindred technical uses such as the manufacture of floor coverings.

The cake is a nutritious and bland concentrated food for cattle, best known in the United States in the form of linseed meal. That obtained by pressing the crushed and heated seed is known as "old process," that obtained by extraction with a fat solvent as "new process." The less valuable by-product, obtained from the threshed seed, consisting of broken pods, fragments of stem, and broken and immature seeds, is also utilized as a cattle food.

MACROSCOPIC STRUCTURE.—Flax *flowers* have five sepals, petals, stamens, and carpels, the latter being united and developing into the five-loculed *pod* up to 1 cm. in length with persistent calyx (Fig. 218). Each locule is divided by a false dissepiment, making the pod ten-celled, dehiscing into ten valves.

A single flattened, ellipsoidal, lustrous, brown or yellow, anatropous *seed*, up to 6 mm. in length, is contained in each cell.

The mucilaginous spermoderm (Fig. 219, *S*), about 0.2 mm. thick, encloses an endosperm (*E*) somewhat thicker, and this in turn the straight embryo consisting largely of two flat cotyledons (*C*). Cross sections of the seed show under a lens in each cotyledon a row of undeveloped fibro-vascular bundles.

Fig. 218.

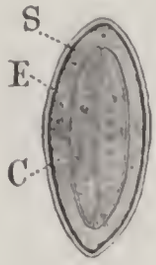


Fig. 219.

Fig. 218.—Linseed. Dehiscing fruit with sepals and pedicel. ×2. (K.B.W.)

Fig. 219.—Linseed. Cross section of seed. *S* spermoderm showing outer white and inner brown tissue; *E* endosperm; *C* cotyledons. ×10. (K.B.W.)

MICROSCOPIC STRUCTURE.—The remarkable calyx and pericarp tissues are described by K. B. Winton;[1] those of the seed by various authors on the microscopy of drugs and foods.

Pedicel.—Analogous to the stalk that yields flax fiber, the tissues are (1) *epiderm* of longitudinally elongated rectangular porous cells and stomata, (2) *cortex* of thin-walled parenchyma, (3) *phloem* of sieve tubes and groups of greatly elongated bast fibers with thick walls and occasional cross striations resembling the fibers of the stalk, and (4) *xylem* consisting of spiral and pitted vessels, wood fibers, and parenchyma.

Calyx.—Both *epiderms* consist of longitudinally elongated wavy-walled cells and stomata with faintly striated cuticle. Several layers of parenchyma through which run small bundles form the *mesophyl*.

Pericarp.—The outer walls (Figs. 220 and 221) consist of five distinct tissues: (1) *epicarp* (*epi*) of somewhat elongated cells, often collapsed, (2) longitudinal rows of detached *crystal cells* (*cr*), lens-shaped in cross section, each with a single monoclinic crystal of calcium oxalate to which the thick wall conforms in inner contour, (3) *hypoderm* of transversely (at the sutures longitudinally) elongated cells (hy^2) with thick, porous walls, the outer walls with projections (hy^1), (4) *mesocarp* (*mes*) of large porous cells, and (5) *endocarp* (*end*) of elongated porous cells like those of the dissepiment, but somewhat smaller.

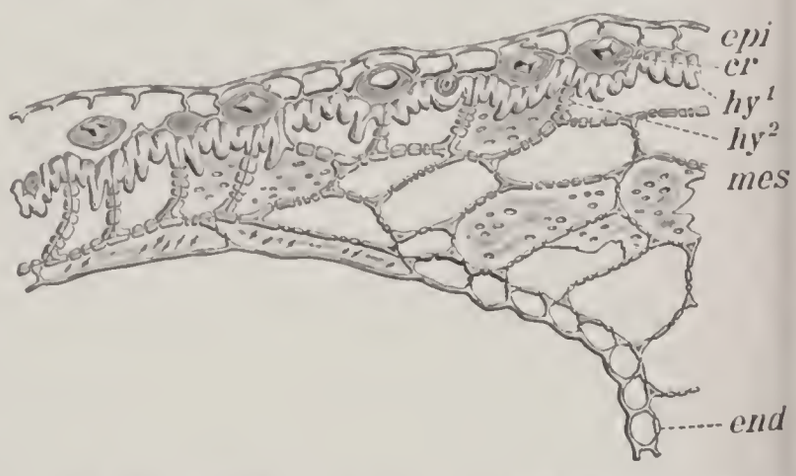


Fig. 220.—Linseed. Pericarp in cross section. *epi* epicarp; *cr* crystal cells; hy^2 hypoderm with hy^1 projections of outer wall; *mes* mesocarp; *end* endocarp. ×160. (K.B.W.)

The transparent papery dissepiments consist of two *epiderms* (Fig.

[1] Bot. Gaz. 1914, **58**, 445.

222) with elongated pitted cells, arranged in groups, and between the two an inconspicuous empty *parenchyma*. The epiderms are striking and characteristic by reason of the parquetry-like arrangement of the cells, the frequent crossing of the cells of the two layers and the sinuous walls at the free edges.

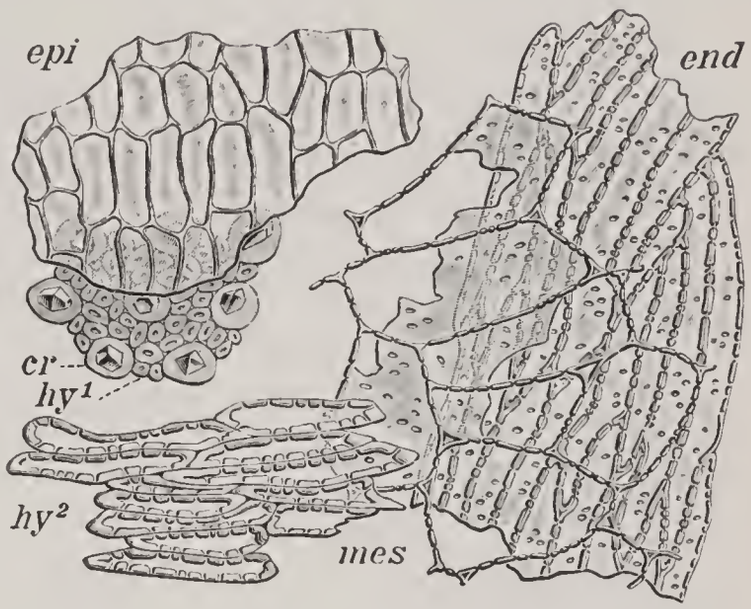


FIG. 221.—Linseed. Elements of pericarp in surface view. *epi* epicarp; *cr* crystal cells; hy^1 projections of outer wall of hy^2 hypoderm; *mes* mesocarp; *end* endocarp. ×160. (K.B.W.)

Spermoderm (Fig. 223, *S*; Fig. 224).—Five distinct tissues, all but the fourth highly characteristic, are classed as spermoderm, although it is quite possible that the inner layer is perisperm: (1) *outer epiderm* (*ep*) of transparent brittle cells with a granular cuticle and mucilaginous contents, (2) *round cells* (*r*) in loose contact, (3) *longitudinal fibers*, (*f*) with thick porous walls, so arranged that groups have their ends in a row, forming a single or double layer, (4) *transverse fibers* (*tr*) with thin walls, and (5) *pigment cells* (*pig*), often nearly square, with finely beaded walls and dark contents.

FIG. 222.—Linseed. Epiderm of dissepiment in surface view. ×160. (K.B.W.)

Commonly the first four layers hold together in the ground material, the combination being especially characteristic.

The *mucilage* of the outer epiderm, which gives the seed its value as a poultice material, is studied in cross section by the method employed for cruciferous seeds, namely, mounting in alcohol and drawing water under the cover glass while under observation. It forms strata with a cavity only on the inner side of the cell. The line separating the cuticle from the outer cell wall is

finely toothed, causing the granular appearance in surface view. The cracking of the layer is in straight lines, although wavy cracks are also present.

Only the inner walls of the *round cells* adjoining the next layer are conspicuously thickened. The *longitudinal fibers*, as is apparent in cross section, are somewhat higher than broad. Treatment with ferric chloride imparts to the contents of the *pigment cells* a dark blue color showing the presence of tannin.

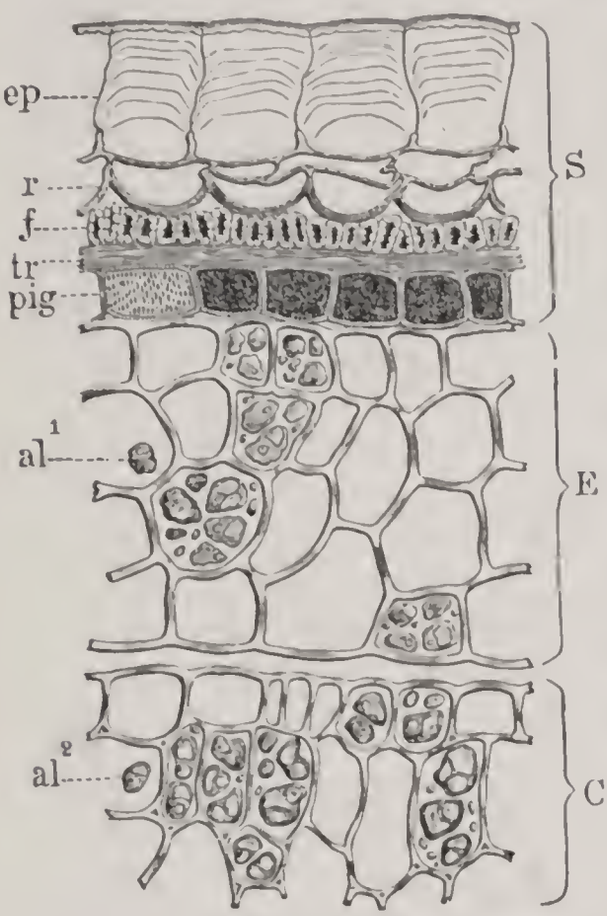


Fig. 223.—Linseed. Cross section. *S* spermoderm: *ep* epiderm, *r* round cells, *f* longitudinal fibers, *tr* transverse fibers, *pig* pigment cells. *E* endosperm with al^1 aleurone grains. *C* cotyledon with al^2 aleurone grains. ×300. (K.B.W.)

Endosperm (Figs. 223 and 224, *E*).—At the edge of the seed the endosperm is only two or three cells thick, in the middle up to five or six cells thick. The walls are somewhat thickened. The contents are *aleurone grains* (al^1) irregular in shape, crinkly in outline, up to 20 μ measured along their longest axis. A globoid is usually apparent in the narrow end and a large crystalloid in the body of the grain.

Embryo (Figs. 223 and 224).—The cotyledons (*C*), which constitute the bulk of the seed, have walls thinner than those of the endosperm. The cells of the *epiderm* (*e*) in surface view are partly large and partly small in groups, the latter forming incipient stomata. *Aleurone grains* (al^2) like those of the endosperm but not so crinkly in outline are the visible contents. To bring out the characters of the aleurone grains, Vogl[1] recommends staining with cochineal or naphthalene blue after extracting with alcohol and ether.

Chief Structural Characters.—Seed flattened, ellipsoidal, lustrous, brown or yellow, up to 6 mm. long, anatropous. Endosperm and embryo about equal in bulk.

Spermoderm made up of mucilaginous epiderm, round cells, thick-walled fibers, crossing thin-walled fibers, and pigment cells, often nearly square with finely beaded walls and dark contents. Endosperm and embryo containing oil and aleurone grains (20 μ) with crystalloid and globoid.

[1] Wicht. Nahr.-Genussm. Berlin, 1899, p. 541.

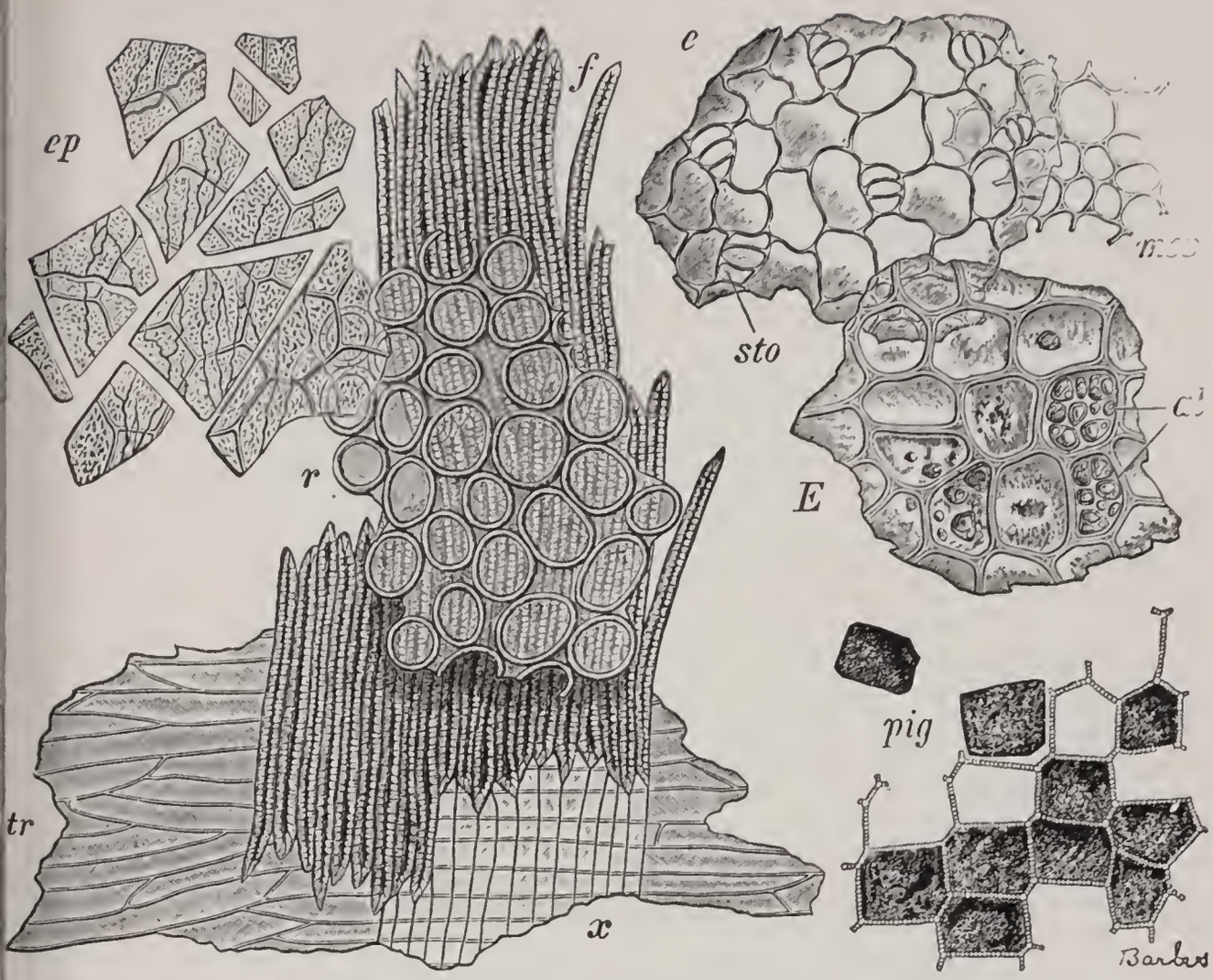


FIG. 224.—Linseed. Elements in surface view. Spermoderm: *ep* outer epiderm, *r* round cells, *f* longitudinal fibers showing at *x* their middle lamellæ on the layer below, *tr* transverse fibers, *pig* pigment cells. *E* endosperm with *al* aleurone grains. Cotyledon: *e* outer epiderm with *sto* immature stomata, *mes* mesophyl. ×300. (K.B.W.)

CHEMICAL COMPOSITION.—Analyses are of value in cattle feeding and in the oil industry. Cleaned seeds, analyzed by Haselhoff,[1] gave the results in the following table:

COMPOSITION OF LINSEED FROM DIFFERENT REGIONS (HASELHOFF)

Source	Water	Protein	Fat	N-f.ext.*	Ash	Acid No.
	%	%	%	%	%	
Königsberg	8.29	22.71	36.47	27.99	4.54	3.6
Mecklenburg	6.88	23.54	34.98	30.79	3.81	2.4
North Russia	7.23	25.10	35.49	27.90	4.28	3.2
South Russia	6.59	26.55	35.33	28.23	3.30	2.4
South America	6.31	23.03	39.47	27.86	3.33	2.8
East Indies	7.09	24.75	37.28	27.61	3.27	2.4

* Includes fiber.

[1] Landw. Vers.-Stat. 1892, **41**, 55.

The following table shows the variation in composition attributable to the source of the seed: [1]

Composition of Linseed Grown in England from Foreign Seed

	Calcutta	Morocco	Odessa	Steepe	Turkey	Berdiansk
	%	%	%	%	%	%
Protein	22.12	23.00	23.50	20.81	22.12	21.56
Fat	36.13	38.36	39.65	30.23	35.09	30.26
Soluble carbohydrates	18.36	19.49	18.58	17.31	18.65	19.52

Examination by Sheppard [2] of seed from different countries and its impurities yielded the following results:

Weight, Impurities, and Oil Content of Linseed (Sheppard)

	U. S. A.	U. S. A.	La Plata	Calcutta	Bombay	South Russia	North Russia
Sp. gr. of seed 15.5° C.	1.1388	.....	1.1415	1.1326	1.1182	1.1375	1.1458
Av. wt. per seed, mg.	4.61	4.53	5.58	5.41	7.88	5.74	4.19
Oily impurities, per cent	1.50	1.01	0.58	4.85	0.81	5.05	3.31
Non-oily impurities, per cent	1.69	1.05	5.64	5.03	2.80	1.71	1.97
Oil in sample, per cent	39.67	39.40	36.98	40.82	41.23	39.11	36.95
Oil in impurities, per cent	10.0	.....	14.1	14.9			

Linseed Cake.—Haselhoff [3] gives the following results showing the difference between pressed and benzine extracted seed:

	Expressed			Extracted		
	%	%	%	%	%	%
Protein	34.13	31.80	36.43	40.14	40.02	40.05
Fat	11.04	10.42	9.86	4.19	2.85	2.95

[1] J. Bd. Agr., London, 1913, **20**, 377; Exp. Sta. Rec. **30**, 637.

[2] J. Ind. Eng. Chem. 1912, **4**, 14.

[3] Loc. cit.

In the United States the ground press cake is known as linseed meal and designated *old process* or *new process*, according as the oil was expressed or extracted with a petroleum solvent. The composition of the two kinds is shown in the following table made up of figures from Jenkins and Winton's Compilation [1] and the average of results as reported by Lindsey, Smith, and Beals:[2]

Composition of Linseed Meal

	Samples	Water	Protein	Fat	N-f.ext.	Fiber	Ash
		%	%	%	%	%	%
Old Process (expressed):							
Jenkins and Winton	21						
Min.	.....	5.60	27.68	5.06	28.38	4.68	4.59
Max.	.....	12.43	38.19	11.57	41.89	13.25	8.16
Aver.	.....	**9.16**	**32.93**	**7.91**	**35.40**	**8.88**	**5.72**
Lindsey, Smith, and Beals	222						
Aver.	.....	**8.5**	**34.4**	**6.8**	**36.5**	**8.3**	**5.5**
NewProcess(extracted):							
Jenkins and Winton	14						
Min.	.....	6.01	27.12	1.30	35.22	7.58	4.96
Max.	.....	13.35	38.35	4.36	48.03	13.99	6.85
Aver.	.....	**10.07**	**33.17**	**2.99**	**38.46**	**9.49**	**5.82**
Lindsey, Smith, and Beals	77						
Aver.	.....	**9.00**	**37.5**	**2.7**	**36.2**	**8.8**	**5.8**

Proteins.—Osborne [3] separated from linseed (1) a crystalline *globulin* evidently identical with the edestin of squash seed, castor bean, and hemp seed, (2) an *albumin*, (3) a *protein*, resembling both albumin and globulin, coagulated by long continued heating at 100° C. as well as by sodium chloride in the presence of acid, (4) a *proteose*, (5) *peptone-like bodies*, and (6) a *glutelin*. In two series of extractions he accounted for 3.42 and 3.48 per cent of nitrogen respectively out of a total of 8.40 per cent as shown in the table on the following page.

The remainder of the protein matter doubtless consists in large part of one or more glutelins which appear to have escaped the attention of specialists in protein chemistry.

[1] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11.**
[2] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.
[3] Am. Chem. J. 1892, **14**, 629.

	A		B	
	Protein	Nitrogen	Protein	Nitrogen
	%	%	%	%
Edestin	13.5	2.51	16.0	2.92
Coagulum	0.8	0.14	1.0	0.17
Proteose	3.7	0.59	1.3	0.16
Glutelin	1.3	0.18	1.6	0.23
	19.3	3.42	19.9	3.48
Residue		0.43		0.46
		3.85		3.94
Loss		4.55		4.46
		8.40		8.40

The *Ultimate Composition* of the linseed proteins as found by Osborne follows:

	Edestin	Coagulum	Proteose
	%	%	%
Carbon	51.48	50.14	49.98
Hydrogen	6.94	6.72	6.95
Nitrogen	18.60	17.54	18.78
Sulphur	0.81	25.70	24.29
Oxygen	22.17		
	100.00	100.00	100.00

The average nitrogen content of the protein matter was found by Osborne to be about 18 per cent, hence the factor 5.55 is suggested for calculation of the protein in linseed meal.

Amino Acids of Linseed Proteins.—Foreman [1] extracted protein matter, consisting chiefly of globulin, from linseed meal by two solvents: (1) 10 per cent salt solution and (2) 0.2 per cent potassium hydroxide solution, the second method being preferred. After hydrolysis, the glutamic acid was separated by freezing the remaining amino acids, esterified, and the esters were extracted by Levene's method, after which Fischer's method was followed.

[1] J. Agr. Sci. 1910, **3**, 358.

PRODUCTS OF HYDROLYSIS OF LINSEED PROTEINS (FOREMAN)

	%
Glycocoll	present
Alanine	1.03
Valine	12.71
Leusine, Isoleucine	3.97
Serine	present
Aspartic acid	1.65
Glutamic acid	11.58
Tyrosine	0.65
Phenylalanine	4.14
Proline	2.85
Tryptophane	present
Arginine	6.06
Lysine	1.19
Histidine	1.66
Ammonia	1.94
	49.43

Noteworthy are the high valine content and the low tyrosine content, the latter probably due to the method.

Jones, Gersdorff, and Moeller [1] report in linseed globulin 1.20 per cent of cystine and 3.98 per cent of tryptophane.

Nitrogen Distribution in Linseed Meal.—The following results by Van Slyke's method are those reported by Hamilton, Uyei, Baker, and Grindley: [2] humin nitrogen 5.09, arginine nitrogen 15.92, cystine nitrogen 1.07, histidine nitrogen 6.14, lysine nitrogen 3.68, mono-amino nitrogen in filtrate from bases 44.55, proline, oxyproline, tryptophane, and non-amino nitrogen in filtrate from bases 3.26, ether-soluble nitrogen 0.12, alcohol-soluble nitrogen 0.37, non-protein nitrogen soluble in cold 1 per cent trichloracetic acid in filtrate from colloidal iron 7.88, amide nitrogen 10.86, and nitrogen lost in method of analysis 2.80; total 101.74 per cent.

Oil.—*Linseed oil* is used as such for food in Europe, especially Russia, and India, also to a limited extent in butter substitutes. Being the drying oil *par excellence*, it is especially suited for paints and varnishes. Those concerned with its technical uses will find its properties fully described in the works of Allen, Lewkowitsch, Revis and Bolton, and others on fats and oils.

Physical and Chemical Values.—The values in the table below suffice to characterize the oil extracted with a suitable solvent from linseed meal:

[1] J. Biol. Chem. 1924, **62**, 183.
[2] J. Am. Chem. Soc. 1923, **45**, 815.

	Sp. gr. 15.5° C.	Refractive index 25° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer	Unsaponifiable matter
						° C.	%
Min.	0.931	1.4782	90	190	170	19	0.5
Max.	0.938	1.4825	145	196	202	21	2.0

Sheppard,[1] in the oils from the seeds described above, determined specific gravity at 15.5° C., refractive index at 25° C., and Hanus iodine number, the range being respectively: 0.9316 to 0.9354, 1.4782 to 1.4815, and 171.1 to 196.4. He was unable to establish any marked differences between the oil from the fresh seed and from seed stored two and one-half years in closed jars, or between the expressed and the extracted oil.

Composition of Linseed Oil.—As shown by the high iodine number, the oil consists largely of acids of a higher degree of unsaturation than oleic acid. Linolic acid of the $C_nH_{2n-4}O_2$ series and linolenic acid, or isolinolenic, or both, of the $C_nH_{2n-6}O_2$ series appear to predominate, but authorities have widely differing views as to the proportion of these acids. Solid acids and oleic acid are doubtless present in smaller amounts. The subject is discussed at length by Lewkowitsch.[2]

Recent investigations by Grossfeld [3] show a range of total solid acids from 6.81 to 13.92 per cent, of which 1.73 to 2.34 per cent is erucic acid and 4.61 to 11.92 per cent is palmitic acid.

Sterols.—Anderson and Moore [4] separated two phytosterols: (1) with melting point 138° C. (acetate 129 to 130°) and polarization −34.22° and (2) with melting point at about 134° C. (acetate 124°) and polarization −31.16°.

Carbohydrates.—The *mucilage* of the epidermal cells of the spermoderm, according to Fendler,[5] has the formula $C_6H_{10}O_5$, is dextrorotatory, and on inversion with acid splits up into a dextrorotatory gum and a sugar. After boiling the solution the liquid may be filtered and the mucilage obtained with an ash content of 10 per cent. Kirschner and Tollens [6] have so purified the substance as to reduce the ash to 0.7 per cent. They state that 5 to 6 per cent of the mucilage occurs in the seed.

[1] Loc. cit.
[2] Chem. Tech. Anal. Oils etc. 1913, **1**, 568; 1914, **2**, 60.
[3] Z. Unters. Lebensm. 1930, **50**, 412.
[4] J. Am. Chem. Soc. 1923, **45**, 1944.
[5] Real. Enzy. ges. Pharm. 1907, **8**, 153.
[6] J. Landw. 1874, **22**, 502.

Glucosides.—*Linamarin*, discovered in the young plant by Jorissen and Hairs,[1] occurs also in the seed. It is a bitter substance, identical or isomeric with the phaseolunatin of Dunstan and Henry,[2] which is split up by the accompanying enzyme *linase*, studied by Armstrong and Eyre, into hydrocyanic acid and reducing sugar. It is separated from an alcoholic extract of the meal as colorless crystalline needles melting at 134° C.

Determinations of hydrocyanic acid by Henry and Auld[3] gave 0.009 to 0.17 per cent in the plant and 0.008 to 0.01 per cent in the seed. The enzyme is rendered inactive by the hot wet process of extraction.

Collins[4] showed that acid of even less strength than that of the gastric juice greatly retards the formation of hydrocyanic acid.

Collins and Blair[5] found that heating at 100° C. with a large bulk of water prevents the enzyme action entirely, although dry heating increases it. A lumpy condition that prevents penetration of a considerable amount of liquid promotes the formation of hydrocyanic acid.

Phosphorus-Organic Compounds.—*Lecithin*, according to Schulze,[6] is present in flax seed to the extent of 0.85 per cent, which is nearly twice that in the cake, namely 0.44 per cent, both calculated to the dry substance.

Phytin and Nucleic Acid.—No results at hand.

Mineral Constituents.—The average composition of the ash as given by Wolff[7] follows:

Ash *	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
3.69	30.63	2.07	8.10	14.29	1.12	41.50	2.34	1.24	0.16

* In seed.

Minor Mineral Constituents. *Iron.*—Seed 85 mg. per kilo, dry basis (McHargue).[8]

Manganese.—Seed 102 mg. per kilo, dry basis (Wester);[9] 38 mg. per kilo, dry basis (McHargue).[8]

Zinc.—Seed 19 mg. per kilo, air-dry basis (Bertrand and Benzon).[10]

[1] Bul. Acad. Roy. Belg. 1891, **21**, 529.
[2] Proc. Roy. Soc. 1903, **72**, 285; 1906, **78B**, 145; 1907, **79B**, 315.
[3] J. Soc. Chem. Ind. 1908, **27**, 428.
[4] J. Chem. Soc. 1912, **102**, II, 586.
[5] Analyst 1914, **39**, 70.
[6] Landw. Vers.-Stat. 1897, **49**, 203.
[7] Aschenanalysen, 1880, p. 160.
[8] J. Agr. Res. 1923, **23**, 395.
[9] Biochem. Z. 1921, **118**, 158.
[10] Bul. soc. hyg. aliment. 1928, **16**, 457.

FRUITS AND NUTS OF THE BURSERA FAMILY

(*Burseraceæ*)

Fruits with oily mesocarp and hard woody endocarp and seeds with oily embryo characterize this family.

The Chinese olive and the pili nut are products of the genus *Canarium*.

CHINESE OLIVE

Canarium spp.

Several species (*C. album*, *C. pimela*, etc.) supply the Chinese with oily fruits which, picked green, are salted like common olives.

MACROSCOPIC STRUCTURE.—Salted specimens from New York Chinatown were 2.5 to 4. cm. long, with a stone nearly as long. The *stone* resembles a pili nut but, at this stage of growth at least, none of the seeds is abortive, the three cavities being of equal size.

MICROSCOPIC STRUCTURE. Pericarp.—Cross sections show: (1) *epicarp* of small, thick-walled cells, (2) *mesocarp* of several layers similar to epicarp, then radial chains, several cells wide, of small cells with thick, porous walls (25 μ), alternating with chains of large cells, and (3) *endocarp* like that of the pili nut but undeveloped.

Vascular bundles occur in the chains of small cells, also *secretory channels* characteristic of the family.[1] Oil forms the outstanding cell contents.

Spermoderm, Endosperm, and Embryo.—As in immature pili nut.

Chief Structural Characters.—Fruit olive-like with triangular spindle-shaped stone.

Mesocarp oily, with chains of large and small cells and secretory channels.

CHEMICAL COMPOSITION.—Blasdale,[2] in the pulp of *C. album*, obtained the following results on the original basis with 73.2 per cent of water and the dry basis, respectively: protein 0.77 and 2.86, pure protein 0.61 and 2.28, amides 0.15 and 0.57, fat 6.55 and 24.46, starch 3.16 and 11.79, sucrose 0.53 and 1.99, reducing sugar 1.95 and 7.26, fiber 4.15 and 15.48, ash 1.50 and 5.61, and undetermined 8.17 and 30.53 per cent.

[1] See DeBary: Comparative Anatomy. London, 1884, p. 525.

[2] U. S. Dept. Agr., Off. Exp. Sta., 1899, Bul. 68.

PILI NUT

Canarium spp.

Among the species said to yield pili nuts are *C. indicum* Stickm., *C. commune* L., *C. polyphyllum*, *C. pachyphyllum*, *C. oleosum* (Lam.) Engl., and *C. luzonicum*, some of which may be synonyms or varieties assigned specific names.

Because of the difficulty in cracking the thick hard shell and the relatively small amount of edible matter, albeit of excellent flavor, this nut is of comparatively small importance. Other names are Java almond and canarium nut.

The same or related species yield oily fruits known as Chinese olives.

MACROSCOPIC STRUCTURE.—As the outward distinctions of the Brazil, paradise, and pili nuts are not generally known, the three are shown together in Fig. 225. The pili *nut* (I), consisting of endocarp and seed, is triangular, spindle-shaped, 4 to 7 cm. long, of a reddish brown color. A section, sawed at right angles to the axis, shows that the shell (*En*) is about 3 mm. in thickness on the sides, more on the angles, and that in addition to the main cell cavity there are two very small ones (*A*), one in the cell wall of each of two sides, representing abortive seeds. The section also shows that the shell tissues are uniform except for a thin inner portion and that the two cotyledons (*C*), constituting the bulk of the embryo, are colorless and fleshy. The spermoderm is thin.

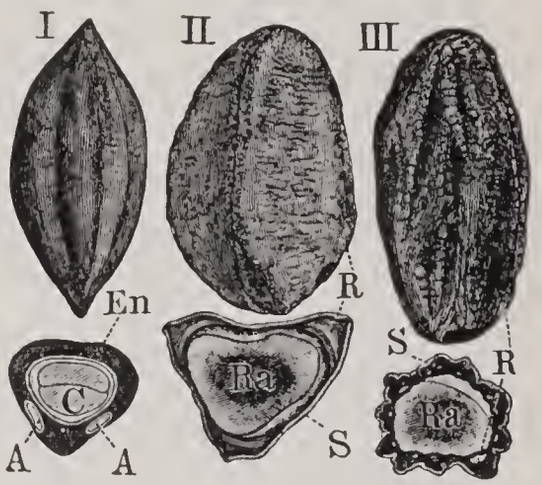


Fig. 225.—I Pili Nut. *En* endocarp; *A* abortive fruit cavities; *C* cotyledons. ×½.

II Brazil Nut. *S* spermoderm; *R* raphe; *Ra* radicle. ×½.

III Paradise Nut. *S* spermoderm; *R* raphe; *Ra* radicle. ×½. (A.L.W.)

MICROSCOPIC STRUCTURE.—Young [1] has made a careful study of the nut. Although belonging to different families and morphologically different, the pili nut in certain histological details, as well as its triangular form, suggests Brazil and paradise nuts. All three have similar stone cells in the shell and aleurone grains in the embryo; also the palisade cells of the inner shell of the pili nut resemble those of the outer epiderm of the other two nuts.

Pericarp.—*Endocarp* tissues are: (1) *stone cells*, mostly isodiametric, with colorless walls and deep red-brown contents, making up the bulk of the shell, and (2) *palisade cells*, up to 1 mm. high, with thick walls and narrow lumen except at the outer end where the lumen is expanded.

[1] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160**, 34.

Spermoderm.—Three layers are present: (1) *outer epiderm* of isodiametric or slightly elongated brown cells, (2) *middle layers* of characterless tissue with raphe, and (3) *inner epiderm* of minute cells (10 μ or less) with spirals or spiral-reticulations.

Endosperm.—One or more layers of colorless empty cells.

Embryo.—The aleurone grains of the cotyledons reach 17 μ. Each large grain contains a distinct crystalloid, also several globoids such as occur in hazel nut. The side in which the globoids occur has an irregular bubbly appearance.

Chief Structural Characters.—Nut triangular, spindle-shaped. Endocarp thick, woody. Spermoderm thin. Embryo with bulky cotyledons.

Outer endocarp of stone cells, inner endocarp of palisade cells up to 1 mm., with enlarged lumen at outer end. Spermoderm with small spiral or spiral-reticulated cells in inner epiderm. Cotyledons contain aleurone grains up to 17 μ, with distinct crystalloid and several globoids.

CHEMICAL COMPOSITION.—Because nuts of this genus are important sources of solid food and edible oils in the East Indian Islands, although little known in the Occident, several analysts have contributed to our knowledge of the composition of the seed and the values of the oil.

Wedemeyer [1] found 13.64 per cent of kernel in the nut of *C. commune*, 65.7 to 68.6 per cent of extracted oil in the kernel, and 34.7 per cent of protein in the cake. Pastrovich [2] obtained 56.1 per cent of expressed oil in the kernel. Grimme [3] found 34.53 per cent of oil in the (dried?) fruit flesh of *C. oleosum* (Lam.) Engl. and 68.63 per cent in the kernel. Krause [4] found 68.23 per cent of ether extract in the kernel of *C. polyphyllum* and 61.01 per cent of protein in the extracted residue. Bolton and Jesson [5] include the " pili nut " (*C. luzonicum*) in their study of less common oil seeds and nuts. Brill and Agcaoili [6] analyzed long and short pili nuts (*C. pachyphyllum*) containing respectively 18.87 and 18.29 per cent of kernel. Wagner and Lampart [7] analyzed kernels of *C. polyphyllum* which they state is the source of " Java almond oil."

The results of Brill and Agcaoili and of Wagner and Lampart are shown in the table on the next page.

[1] Seifens. Ztg. 1907, **34**, 26.
[2] Chem. Z. 1907, **31**, 782.
[3] Chem. Rev. Fett-Harz Ind. 1910, **17**, 78.
[4] Der Tropenpflanzer, 1913 (7), 147.
[5] Analyst 1915, **40**, 3.
[6] Phil. J. Sci. 1915, **10**, 105.
[7] Z. Unters. Nahr.-Genussm. 1915, **29**, 105.

COMPOSITION OF PILI NUT KERNELS

	Water	Protein	Fat	Sucrose	Reducing sugar	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%	%
B. and A.:								
C. pachyphyllum:								
Long	2.79	12.06	74.39	0.88	0.45	5.64	2.15	2.97
Short	2.90	11.88	72.53	0.66	1.35	7.12	2.42	3.15
W. and L.:								
C. polyphyllum	4.87	13.94	69.58	7.26			0.84	3.51*

* P_2O_5 1.16 per cent.

Proteins.—The aleurone grains seen under the microscope indicate that a crystalline protein is present in this nut, but as yet no studies appear to have been recorded.

VALUES OF CANARIUM OILS

	Sp. gr. 15.5° C.	Ref. index 40° C.	Melting point	Sapon. No.	Iodine No.	Reichert-Meissl No.	Fatty acids, titer
			° C.				° C.
C. commune:							
Wedemeyer	0.8953	1.4590	....	193.5	64.7	0.1	37.2
Pastrovich	....	1.4601	28–18	194.3	65.6	0.0	41.0
C. oleosum:							
Grimme	....	1.4592	....	197.0	63.0		
C. polyphyllum:							
Krause	....	1.4681	30	200.2	59.7	4.4	
Wagner and Lampart	0.8978	1.4576	22	189.7	52.9	0.33*	38.0
C. pachyphyllum:							
Brill and Agcaoili:							
Long	0.9003	1.4583	....	192.6	61.2	3.3	
Short	0.9003	1.4584	....	186.8	59.6	2.2	
C. luzonicum:							
Bolton and Jesson	....	1.4583	29	197.0	57.1		

* Polenske number 0.4.

Oil.—The somewhat extensive investigations made of the oils of the various species show considerable variation. The figures in the foregoing table on specific gravity and refractive index were in most cases

recalculated to uniform temperatures using a correction for each degree of 0.00064 for specific gravity (Allen) and 0.00036 (Tolman) for refractive index. The responsibility for the scientific nomenclature of the species rests with the authors, who fail in some cases to give authorities.

Composition of Canarium Oil.—Pastrovich [1] found 95.36 per cent of insoluble fatty acids (Hehner number) in the sample he examined and by Hazura's method obtained the following percentages of fatty acids in the insoluble fatty acids.

	%
Stearic acid	15.0
Palmitic acid	29.5
Oleic acid	43.0
Linolic acid	12.5
	100.0

Carbohydrates.—Brill and Agcaoili [2] report 4.31 and 5.11 per cent of starch by difference in the two samples analyzed by them; these figures, however, do not represent true starch (which is absent) but undetermined matter and error, hence they are not included in the table on the foregoing page.

Mineral Constituents.—No results available.

The gaps in the literature on the composition of the nuts, as well as the pericarp tissues, of this family are noteworthy. Studies of the proteins and a revision of the work on the composition of the oils are particularly desirable.

[1] Loc. cit.

[2] Loc. cit.

NUTS OF THE SPURGE FAMILY

(*Euphorbiaceæ*)

One representative of the group, namely candlenut, is here described because of its use as a cattle food.

CANDLENUT

Aleurites triloba Forst. = *A. moluccana* Willd.

Fr. Bancoulier. It. Bankoul. Ger. Bankulnuss.

The candlenut tree, probably a native of Malasia, is grown throughout the tropics for its oily nuts. Although the oil pressed from them, because of its purgative properties, is not suited for food and the close relationship to the castor bean suggests similar toxic properties, the nuts after roasting are eaten by the natives and the cake is used as a cattle food.

MACROSCOPIC STRUCTURE.—The *nut* resembles an English walnut in size, shape, and method of separation into halves. It has a shell (spermoderm) up to 5 mm. thick, a fleshy endosperm, and an embryo with thin but broad cordate cotyledons and a short radicle.

MICROSCOPIC STRUCTURE.—The structure, resembling closely that of the castor bean, has been studied by Wichmann [1] and later authors.

Spermoderm.—The two outer layers are removed before the seed is placed on the market. The remaining layers are (1) *thin-walled palisade cells*, (2) *thick-walled palisade cells*, (3) *parenchyma cells*, with diagonal pores, containing masses of calcium oxalate, and (4) *compressed parenchyma*.

Moeller [2] and Winton [3] show the thick-walled palisade cells as forming a single cell layer analogous to the corresponding layer of the castor bean and state that they are 1.5 to 2.5 mm. high. Collin and Perrot [4] show the cells end to end in radial rows as they may appear to be if a razor section is cut diagonal to the axes of the cells.

[1] Uhlworm: Bot. Centralb. 1880, **1**, 446. Harz: Samenkunde. Berlin, 1885, p. 840.

[2] Mikroskopie Nahr.-Genussm. Berlin, 1905, p. 327.

[3] Microscopy of Vegetable Foods. New York, 1906, p. 224.

[4] Les résidus industriels. Paris, 1904, p. 136.

Endosperm and Embryo.—Both contain aleurone grains up to 25 μ, each containing a crystalloid and one or more globoids.

Chief Structural Characters.—Nut (seed) size and shape of English walnut. Spermoderm 5 mm. thick. Endosperm bulky. Embryo with broad, thin cotyledons.

Inner spermoderm with thin- and thick-walled palisade cells and parenchyma cells containing calcium oxalate. Endosperm and embryo with aleurone grains (25 μ), each containing crystalloid and one or more globoids.

CHEMICAL COMPOSITION.—A representative analysis of this nut by Carles [1] shows as follows:

Water	Protein	Fat	N-f. ext.	Sucrose	Fiber	Ash	K_2O	P_2O_5
%	%	%	%	%	%	%	%	%
9.10	17.41	61.50	5.88	1.80	2.74	3.37	1.18	1.69

Oil. *Physical and Chemical Values.*—Although Fendler [2] notes the drying properties of the oil, he reports a low iodine number (114.2); Lewkowitsch [3] on the other hand reports an abnormally high iodine number (163.7). Other results by these authors, also those by an analyst of the Imperial Institute,[4] Lespinasse,[5] West and Montes,[6] and Georgi [7] are summarized below:

Sp. gr. 15° C.	Refrac. index 20° C.	Solidifying point	Saponification No.	Iodine No.	Reichert–Meissl No.	Fatty acids, titer
		°C.				°C.
Min. 0.9254	1.4773	−15	175	137	1.2	12.5
Max. 0.9305	1.4774	−15	214	149	2.0	17.8

Composition.—West and Montes[6] give the following figures based on their results:

Glycerides of:	%
Oleic acid	56.9
Linolic acid	33.4
Linolenic acid	6.5
Solid acid	2.8

[1] J. Pharm. Chem. 1879, **30**, 163.
[2] Z. Unters. Nahr.-Genussm. 1903, **6**, 1025.
[3] Chem. Tech. Anal. Oils etc. London, 1914, **2**, 87.
[4] Bul. Imp. Inst. 1907, **4**, 136; 1912, **10**, 44.
[5] Ann. fals. 1919, **12**, 152.
[6] Philippine J. Sci. 1921, **18**, 619.
[7] Malay. Agr. J. 1922, **10**, 202.

NUTS OF THE CASHEW FAMILY

(*Anacardiaceæ*)

Various tropical fruits described in Volume II belong to this family. The cashew nut, although containing about 10 per cent of starch, and the pistachio nut are rich in oil.

CASHEW NUT

Anacardium occidentalis L. = *Cassurium pomiferum* Lem.

Fr. Noix d'acajou. Sp. Marañon. Ger. Akaschunuss.

A native of Brazil, where it grows luxuriantly both wild and cultivated, the cashew tree is cultivated throughout the tropics of the Old and New World. The pericarp of the fruit proper contains cardol and anacardic acid, both highly irritating constituents. The juice produces blisters on the skin similar to those of poison ivy and sumac. The noxious constituents are destroyed by roasting, and the embryo separated after this treatment is sweet and wholesome—the cashew nut of commerce. The edible fleshy peduncle (cashew apple), at the top of which the nut is borne, is described in Volume II under Fruits.

Hoepner and Burmeister [1] note that cashew nut flour is sometimes added to almond paste.

MACROSCOPIC STRUCTURE.—Panicles of both staminate and perfect *flowers* are produced by the same tree. The calyx is five-cleft; the corolla consists of five narrow, salmon-colored petals. There are ten or fewer stamens. The one-celled ovary has a slender style attached at one side.

The *fruit* proper (Fig. 226, below) resembles a giant bean kernel, reaching 4 cm. in length. It consists of colorless or yellow epicarp and endocarp between which is the black mesocarp with resin cavities. Epicarp and endocarp are merged at the sinus with a rounded mass of hard tissue. The cotyledons are long and fleshy, the radicle is short and narrow.

[1] Z. Öffent. Chem. 1913, **19**, 185.

MICROSCOPIC STRUCTURE.—Young [1] has studied the histology of all parts but the fleshy peduncle.

Pericarp.—Although it is not edible, its structure is instructive. The layers as seen in cross section are (1) *epicarp* of palisade cells, up to 60 μ high and 35 μ broad, wavy-walled in surface view, and stomata, (2) *hypoderm*, ten or more cells thick, of regularly arranged, rather small, colorless cells with thick, often beaded walls, (3) *mesocarp* of cells variously elongated, with black contents, also large essential oil cavities often up to 500 μ, and fibro-vascular bundles, (4) *narrow palisade cells*

Fig. 226.

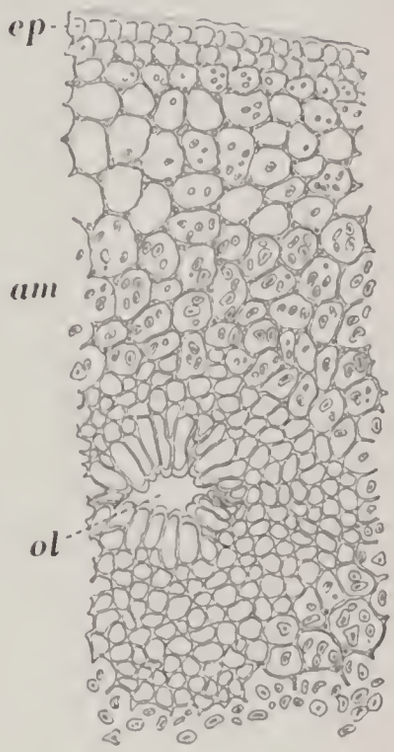


Fig. 227.

Fig. 226.—Cashew. I Cotyledons (above) and radicle (below), separated after roasting. II Nut surmounting edible peduncle. III Nut in cross section. Epicarp and endocarp confluent with rounded hard mass *x* at sinus. Mesocarp (dark) with oil cavities. ×½. (A.L.W.)

Fig. 227.—Cashew. Cotyledon in cross section. *ep* epiderm; *am* starch parenchyma; *ol* oil cavity surrounded by palisade cells. ×160. (A.L.W.)

up to 30 μ high, and (5) *endocarp* of palisade cells up to 250 μ high and still higher on the dorsal edge.

The palisade cells of the *epicarp* diminish in height about the stomata, those adjoining the guard cells being of about the same height. Young refers to stone cells adjoining the palisade cells of the endocarp. The cells here form a rather uniform single layer with thick walls but they stain blue with chlorzinc iodine and are not stone cells.

In surface view the *endocarp* cells are elongated, the longer diameter reaching 45 μ.

[1] U. S. Dept. Agr., Bur. Chem. 1912, **160**, 32.

Spermoderm.—Cross sections, after warming with chloral hydrate, show: (1) *compressed cells* forming a light-colored layer, a number of cells thick, (2) well-defined *brown cells* passing into (3) light colored *compressed cells.*

The *raphe bundles* occur between the first and second layers.

Endosperm.—An indistinct single layer of round cells, containing aleurone grains, is probably endosperm. The *aleurone grains* are best seen in surface mounts treated with water and iodine in potassium iodide.

Embryo. *Cotyledon* (Fig. 227).—The *epidermal cells* (*ep*) are small and starch-free. A *subepidermal tissue*, several cells thick, is also starch-free but passes into *starch parenchyma* (*am*) without noticeable change of cell form.

The *starch grains* (Fig. 227, *am*; Fig. 228) are elliptical, kidney- or wedge-shaped, up to 12 μ long, with an elongated cleft ("hilum"). They resemble mango starch but are smaller.

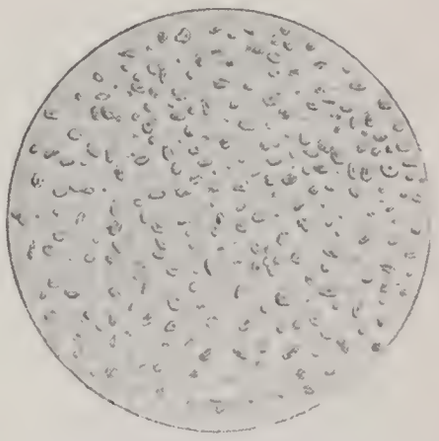


Fig. 228.—Starch from cashew nut. ×160. (A.L.W.)

Distributed through the starch parenchyma are procambium bundles and small *essential oil cavities* (Fig. 227, *ol*), immediately surrounded by an irregular row of palisade cells, and outside of these a mass of small isodiametric starch-free cells. These cavities resemble those of umbelliferous roots (parsnip, carrot, celeriac), and petioles (celery, parsley) but not at all the cavities in the peduncle and pericarp of myrtaceous fruits.

Chief Structural Characters.—Cotyledon: epiderm starch-free; starch-free subepiderm passes into starch parenchyma; starch grains up to 12 μ, elongated kidney- or wedge-shaped, with cleft; essential oil cavities surrounded by mass of small cells and immediately by row of palisade cells.

CHEMICAL COMPOSITION. Husk.—The pericarp or husk, according to Joseph and Sudborough,[1] contains 39.8 per cent of an oil consisting of anacardic acid, cardol, and fatty matter. Anacardic acid ($C_{22}H_{32}O_3$) is a brown crystalline substance. Its ammonium salt is a vermifuge. Cardol ($C_{32}H_{52}O_4$) is a dark brown oily substance used in medicine as a vesicatory. The analytical values of the husk oil, given by the authors named above, are: specific gravity at 26° C. 1.0131, refractive index at 41.5° C. 1.5158, saponification number 119, iodine number 296, and acid number 107.

[1] J. Ind. Inst. Sci. 1923, **5**, 133.

Kernel.—About 30 per cent of the nut consists of kernel, analyses of which by Theopold [1] and Thompson [2] follow:

Composition of Cashew Kernels

	Water	Protein	Fat	Reducing substances	Starch	Fiber	Ash
	%	%	%	%	%	%	%
Theopold.....	3.80	9.70	47.15	8.10	8.90		
Thompson.....	6.78	14.44	41.57	.....	.....	1.27	2.59

Oil.—Georgi [3] states that the nut contains 40 to 45 per cent of oil but it is extracted with difficulty owing to the husk. The cake contains 23.4 per cent of protein. The yield of oil according to Patel, Sudborough, and Watson [4] is 42.12 per cent.

West and Cruz [5] state that the kernels contain 47.2 per cent of oil.

Physical and Chemical Values.—The physical values in the table which follows have been recalculated in some instances to uniform temperatures:

Values of Cashew Kernel Oil

	Sp. gr. 15.5° C.	Refractive index 25° C.	Saponification No.	Iodine No.	Acid No.	Unsaponifiable matter
						%
Theopold:						
Min.....	.....	1.4646	182	77		
Max.....	.....	1.4651	187	83.6		
H. and B.....	.....	1.4672	195	84	5.3	
Georgi.....	0.919	1.4752	187.3	78.4	5.5*	0.6
W. and C.....	0.9176	1.4683	187	85.2	1.45	1.47

* Percentage calculated as oleic acid.

Georgi [3] found that the melting point of the fatty acids is 28° C. and the mean molecular weight is 284.6.

According to West and Cruz [5] the percentages of constitutents in the

[1] Pharm. Centralh. 1908, **49**, 1057.
[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.
[3] Malay. Agr. J. 1922, **10**, 301.
[4] J. Ind. Inst. Sci. 1923, **6**, VI, 111.
[5] Phil. J. Sci. 1923, **23**, 337.

oil are: olein 80.4, stearin 17.3, and unsaponifiable matter 1.5; total 99.2 per cent.

Patel, Sudborough, and Watson [1] found that 18.2 per cent of the fatty acids are saturated and 81.8 per cent unsaturated.

Composition of Cashew Kernel Oil (Patel et al.)

Glycerides of:	%
Lignoceric acid	0.50
Stearic acid	11.24
Palmitic acid	6.40
Oleic acid	73.77
Linolic acid	7.67
Unsaponifiable matter	0.42
	100.00

PISTACHIO NUT

Pistacia vera L.

Fr. Pistache. Sp. Pistacho. It. Pistacchio. Ger. Pistazie.

The pistachio tree is a Syrian species grown in the Mediterranean region since about the Christian era and to some extent in California since the latter half of the nineteenth century. Syria, Sicily, and Persia lead in its cultivation.

Fig. 229.—Pistachio Nut. I whole nut (salted). II shelled nut. III nut, deprived of spermoderm showing fleshy cotyledons and *R* radicle. ×1. (A.L.W.)

Pistachio nuts, or green almonds, are sold either unshelled and salted or else shelled. The brine in which the unshelled nut is soaked forms a film on the surface of the shell and on the kernel within. Shelled nuts are eaten as such or are used in pastries and confectionery where they are recognized by the green color of the cotyledons and the purple skin.

MACROSCOPIC STRUCTURE.—The female *flowers* have three to four calyx divisions and as many styles, but the ovary is one-celled and a corolla is wanting. The *fruit* is a dry drupe with a thin mesocarp and an endocarp or shell about 0.5 mm. thick, gaping at the apex (Fig. 229, I), which is the only pericarp tissue present in the commercial unshelled nut. On soaking off the salt the shell is seen to be longitudinally striate, of a buff color.

The anatropous *seed* (II) is slightly flattened at both ends in planes at right angles to each other and has a depression on the ventral side

[1] Loc. cit.

near the base. The spermoderm is blue-red on the dorsal side, colorless on the ventral side, but appears green on account of the cotyledons seen beneath. Both dorsal and ventral sides have a ridge which is especially marked at the apex. In the dorsal ridge is the raphe. After softening in water a skin consisting of spermoderm and colorless perisperm and endosperm separates. The fleshy green cotyledons (III) make up the bulk of the seed. The minute radicle (*R*) is situated in the ventral edge near the apex.

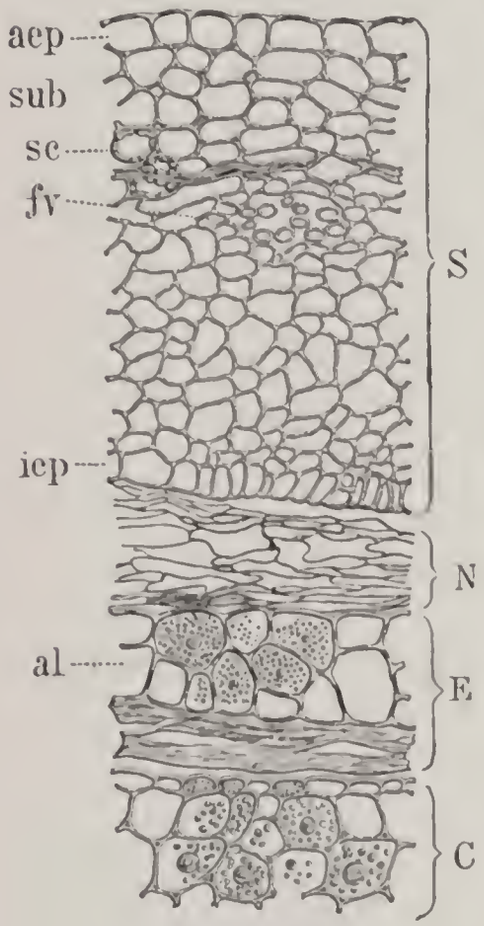


Fig. 230.

MICROSCOPIC STRUCTURE.—Winton[1] and Young[2] describe the structure in detail.

Pericarp.—The *endocarp* (Fig. 231, *st*) is made up of much-branched and interlocking colorless stone cells. In razor sections and the powder their nature is obscure

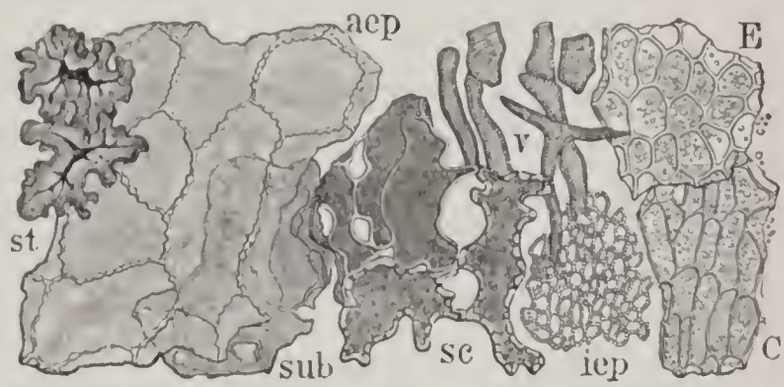


Fig. 231.

Fig. 230.—Pistachio Nut. Seed in cross section, dorsal side. *S* spermoderm: *aep* outer epiderm, *sub* subepiderm, *sc* sclerenchyma, *fv* bundle, *iep* inner epiderm. *N* perisperm. *E* endosperm with *al* aleurone cells. *C* cotyledon containing aleurone grains. ×160. (A.L.W.)

Fig. 231.—Pistachio Nut. Elements in surface view. *st* stone cells of endocarp; *v* vessels of bundle; *C* outer epiderm of cotyledon. Other reference letters as in Fig. 230. ×160. (A.L.W.)

but is beautifully distinct after maceration with strong sodium hydroxide.

Spermoderm (Fig. 230, *S*; Fig. 231).—This is thickest on the dorsal side. It consists of (1) *outer epiderm* (*aep*) of polygonal isodiametric or moderately elongated cells, up to 80 μ long, with beaded walls, (2) *subepiderm* (*sub*), one or more cells thick, of spongy parenchyma, (3) *middle parenchyma* with sclerenchyma cells (*sc*) and fibro-vascular

[1] Microscopy of Vegetable Foods. New York, 1st Ed. 1906, p. 315.

[2] U. S. Dept. Agr., Bur. Chem. 1912, Bul. 160.

bundles (*fv*) of the raphe and its branches, and (4) *inner epiderm* (*iep*) of very small, polygonal, distinctly beaded, relatively thick-walled cells except on the dorsal side where they are thin-walled and characterless.

The blue-red color present in the cells on the dorsal side is soluble in water. With alkalies it becomes green.

Perisperm (Fig. 230, *N*).—This is evident in cross section on the dorsal side as a compressed layer.

Endosperm (Figs. 230 and 231, *E*).—One or more rows of *aleurone cells* and an inner compressed tissue are evident in cross section. The aleurone grains range up to 5 μ but are mostly scarcely measurable.

Embryo.—In the *epiderm* of the cotyledons the aleurone grains are minute but increase in size toward the interior where they reach a maximum of 14 μ. Sometimes small starch grains occur in the outer portion.

Chief Structural Characters.—Endocarp (shell) buff, striate; spermoderm blue-red (green with alkali) on dorsal side; endosperm and perisperm thin, colorless; cotyledons bulky, green; radicle minute.

Endocarp cells much-branched, interlocking. Spermoderm with beaded outer epiderm, sclerenchyma cells in middle parenchyma, and small, beaded cells forming inner epiderm. Endosperm and cotyledon containing small aleurone grains, in latter up to 14 μ.

CHEMICAL COMPOSITION.—Analyses of 2 samples of the shelled pistachio nuts by Woods and Merrill [1] follow:

	Water	Protein	Fat	Total carbohydrates	Ash
	%	%	%	%	%
First quality	4.2	22.3	54.0	16.3	3.2
Second quality	4.3	22.8	54.9	14.9	3.0

The composition of the shelled nut, as given by an anonymous author,[2] corresponds closely with the above except that the water content is 7.4 per cent and the fiber (2.5 per cent) is separately given.

Oil.—According to De Negri and Fabris,[3] the oil is made in small lots and used in food products.

Physical and Chemical Values.—The figures given by De Negri and Fabris follow: specific gravity at 15° C. 0.9185, refractive index at 25° C.

[1] Maine Agr. Exp. Sta. 1899, Bul. **54.**

[2] Bul. Imp. Inst. 1917, **15,** 267.

[3] Ann. Lab. Chim. Gabelle, 1893, p. 220.

1.4672, Maumené number 44 to 45, saponification number 191 to 192, iodine number 86 to 88, and fatty acids, titer 13 to 14° C.

Merrill,[1] in oil obtained by ether extraction, found: specific gravity at 15.5° C. 0.9188, refractive index at 25° C. 1.4669, and iodine number 83.8.

Composition.—Beythien [2] obtained in the examination of 2 samples of pistachio oil closely agreeing results, the averages of which are here given, together with results by Dhingra and Hilditch[3] showing the composition of the fatty acids:

Composition of Pistachio Oil

	Beythien	Dhingra and Hilditch
	%	%
Stearic acid	.....	1.6
Palmitic acid	16.90	8.2
Myristic acid	.....	0.6
Oleic acid	54.41	69.0
α-Linolic acid	6.92	19.8
β-Linolic acid	11.50	
Oxidized acid	about6.00	
Glycerol residue	4.30	
Unsaponifiable matter	0.23	0.8
	100.26	100.0

[1] Maine Agr. Exp. Sta. 1900, Bul. **65.**

[2] Pharm. Zentralh. 1929, **70,** 551.

[3] J. Soc. Chem. Ind. 1931, **50,** 9.

SEEDS OF THE MALLOW FAMILY

(*Malvaceæ*)

Okra, the vegetable (Volume II), and two species of cotton are the important food plants of the family.

COTTONSEED

Gossypium herbaceum L.

Fr. Cotonnier. Sp. Algodón. It. Cotone. Ger. Baumwollsamen.

Common or upland cotton, an Indian plant, although known to the Greeks before the Christian era, was cultivated little, if at all, in the Mediterranean region until the Mohammedan invasion. Cotton was used as a textile in the Western Hemisphere at the time of its discovery but it is probable that it was obtained from *G. barbadense* or some species other than *G. herbaceum*. The introduction of upland cotton into the United States appears to have been shortly before the Revolution.

Sea island cotton (*G. barbadense*) is considered in the following chapter. Tree cotton (*G. arboreum* L.), an African plant, is of small importance.

Authorities differ widely as to the taxonomy of the genus. Todaro [1] considers that there are fifty-four species, Parlatore [2] seven with two doubtful. Masters,[3] agreeing on the whole with Parlatore, combines some of his species and De Candolle emphasizes only three as here given.

The utilization in the United States of cottonseed, which unlike linseed is a true by-product of the fiber crop, dates from shortly after the middle of the nineteenth century, and up to near the end of that century only the extracted " meats " or decorticated kernels were used for feeding, the hulls being burned on the plantation.

MACROSCOPIC STRUCTURE.—The attractive pale yellow *flower* resembles that of the single hollyhock, its near relative, in form and size. It has an involucre of three calyx-like bracts, five sepals, and five petals. The large *pod* or boll has up to five cells containing a number of seeds each with both long and short hairs on the spermoderm. After

[1] Relazione della Coltura dei Cotoni in Italia, segnita da una Monographia del Genere Gossipium. Rome and Palermo, 1877–78.

[2] Le Specie dei Cotoni. Florence, 1866.

[3] Oliver: Fl. Trop. Afr., p. 210. Hooker: Fl. Brit. Ind., p. 346.

ginning, numerous short hairs remain on the seed, thus differing from sea island cottonseed, which is practically naked.

The anatropous *seed* (Figs. 232 and 233) after removal of the fiber is pointed ovoid, dark brown or nearly black, and varies up to over 12 mm. in length. Both hilum and micropyle are located at the pointed lower end, the chalaza at the upper end toward one side. The raphe forms a slight ridge. The spermoderm is about 0.3 mm. thick. On the inner surface it is brown with a white opalescence. On removal of the spermoderm a thin skin, consisting of perisperm and endosperm, is seen to

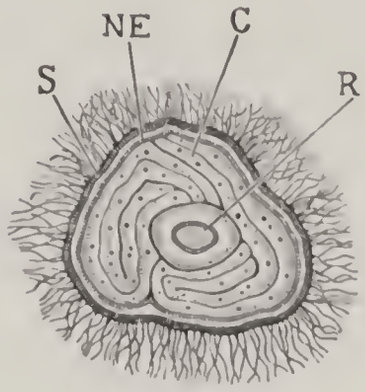


Fig. 232.

Fig. 233.

Fig. 232.—Cottonseed. Cross section. *S* spermoderm; *NE* perisperm and endosperm; *C* cotyledons; *R* radicle. ×4. (A.L.W.)

Fig. 233.—Cottonseed. Longitudinal section. ×4. (A.L.W.)

form an inner membrane immediately surrounding the embryo which constitutes the bulk of the seed.

Cross and longitudinal sections show that the radicle is long, and the cotyledons are both rolled about it and curiously folded above it; furthermore, that the white flesh of the cotyledons is dotted with numerous dark spots, the resin cavities. On soaking for a day or two in water the kidney-shaped cotyledons may be unfolded.

MICROSCOPIC STRUCTURE.—The histology is briefly described in the treatises, notably those of Harz [1] and Böhmer,[2] and in detail in papers by Von Bretfeld,[3] T. F. Hanausek,[4] and Winton.[5]

[1] Samenkunde. Berlin, 1885, p. 740.

[2] Dammer: Lexikon der Verfalschungen, 1887, II, p. 681. Kraftfuttermittel. Berlin, 1903, p. 558.

[3] J. Landw. 1887, **35**, 29.

[4] Z. allg. oesterr. apoth.-Ver. 1888, **26**, 569, 591.

[5] Analyst 1904, **29**, 44. Connecticut Agr. Exp. Sta. Rep. 1903, p. 175.

Spermoderm (Fig. 234, *S*; Fig. 235).—Through the raphe the thickness reaches 400 μ, in other parts it is somewhat less (maximum 350 μ). There are four well-differentiated outer layers and a fifth inner layer which shows considerable variation from without inward:

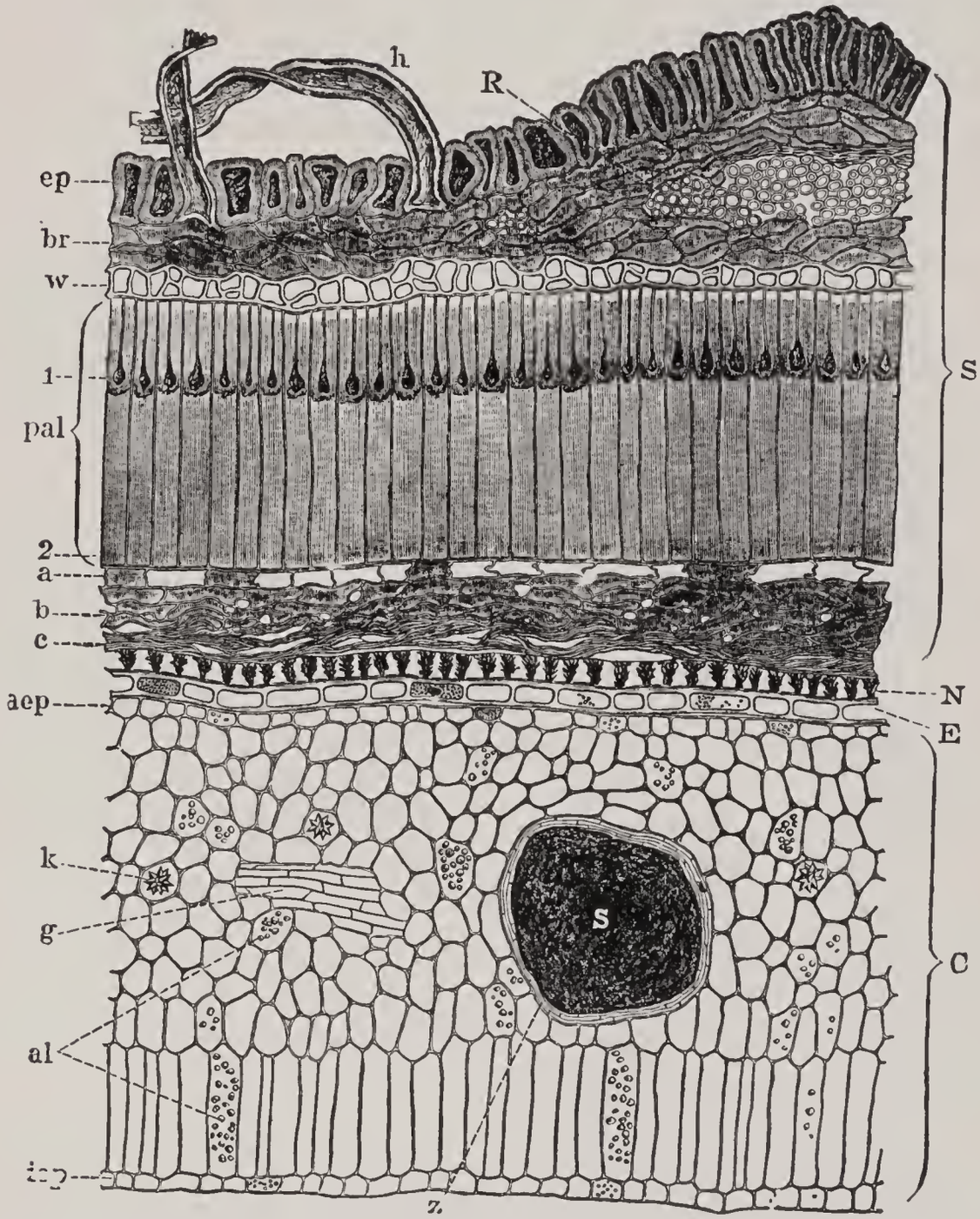


FIG. 234.—Cottonseed. Cross section. *S* spermoderm: *ep* outer epiderm with *h* hair, *br* subepiderm with *R* raphe, *w* colorless cells, *pal* palisade cells, *a*, *b*, *c* inner brown layers. *N* perisperm. *E* endosperm. *C* cotyledon: *aep* outer and *iep* inner epiderms, *k* crystals, *al* aleurone grains, *g* procambium bundle, *s* resin cavity surrounded by *z* mucilage cells. ×160. (A.L.W.)

(1) *outer epiderm* (*ep*) of thick-walled cells with dark contents, thin-walled stomata (*sto*[1]), and hairs (*h*, *h*[1]), (2) *subepiderm* (*br*) of thin-walled cells with brown contents, (3) *colorless cells* (*w*) empty or occasionally containing oxalate crystals, (4) remarkable *palisade cells*

(*pal*, *pal*^{1}, *pal*^{2}) about 150 μ high with a faint outer light line adjoining the outer ends, and (5) composite inner *brown layer* (*a*, *b*, *c*) varying from polygonal cells, with brown contents without, to empty spongy parenchyma within.

The cells of the *outer epiderm* are conspicuous because of their thick, stratified yellow walls and dark contents. About the hairs they form rosettes. The *hairs* have the well-known characters of cotton fiber, being flattened and twisted and usually having walls much thinner than the lumen.

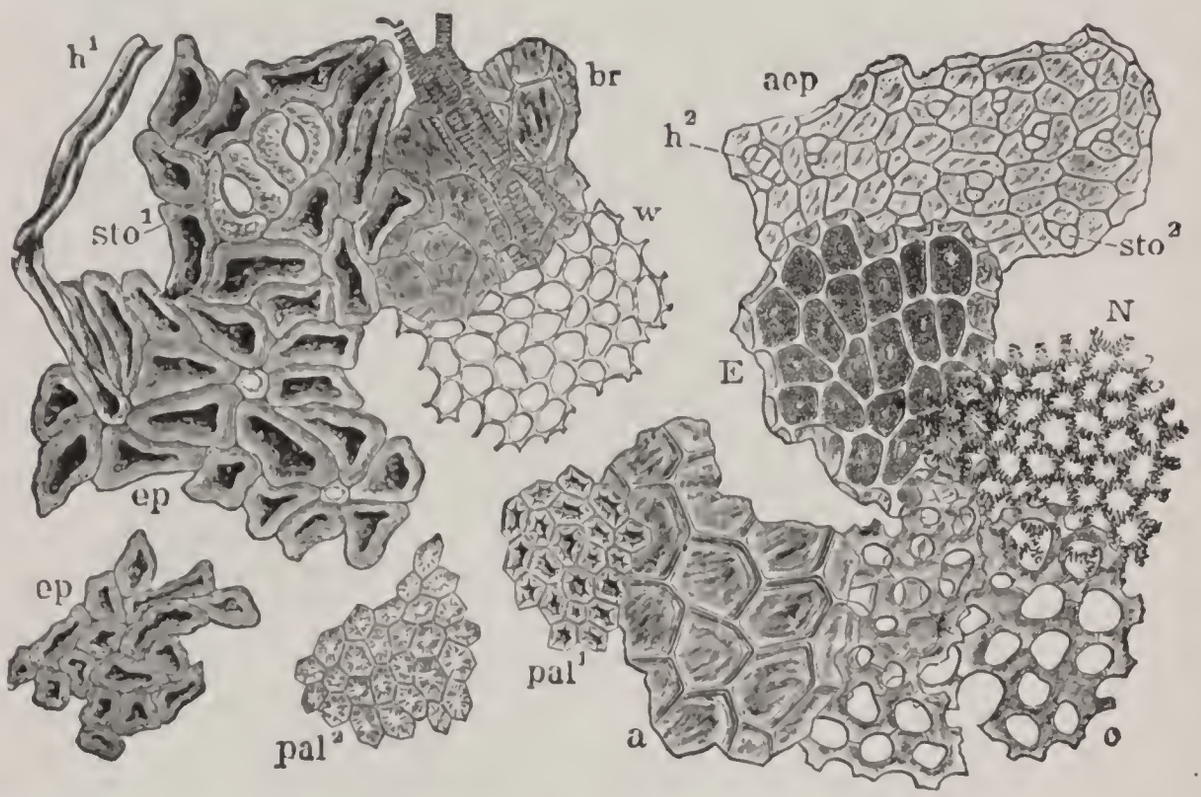


FIG. 235.—Cottonseed. Elements in surface view. Spermoderm: *ep* outer epiderm with h^1 hair and *sto*^{1} stomata, *br* subepiderm, *w* colorless cells, *pal*^{1} and *pal*^{2} palisade cells at different foci, *a* and *c* inner brown layers. *N* perisperm. *E* endosperm. *aep* outer epiderm of cotyledon with h^2 multicellular hair and *sto*^{2} immature stomata. ×160. (A.L.W.)

Chief interest centers in the *palisade cells* which are similar only to the corresponding layer of kapok seed and are distinguished from these by being one-third higher. Von Bretfeld has shown that in the outer third the cells have colorless cellulose walls (blue with chlorzinc iodine), giving a play of colors with polarized light and a narrow lumen ending in a bulbous enlargement, while in the inner two-thirds they have yellow, lignified walls (yellow with chlorzinc iodine), giving no play of colors with polarized light, and no lumen visible in cross section of the seed, although in tangential section faint radiating lines are visible. Cells isolated with Schultze's macerating solution and treated with chromic acid show their structure.

Perisperm (Figs. 234 and 235, *N*).—In the thin skin which separates the spermoderm from the embryo the perisperm is distinguished from the endosperm by the curious fringe on the walls, hence Hanausek's name "fringe cells."

Endosperm (Figs. 234 and 235, *E*).—Only a single layer of *aleurone cells* is present. The aleurone grains are minute.

Embryo (Figs. 234 and 235).—In scrapings of the cotyledons (*C*) the epidermal layers may be studied. The *outer epiderm* (*aep*) consists of (1) polygonal cells, (2) pairs of cells (*sto*^{2}) which later become guard cells of stomata, and (3) oval jointed hairs (*h*^{2}), most abundant where the cotyledons join the hypocotyl.

Cross sections, extracted with ether or gasoline, bring out other details of structure. Except for a single layer of *palisade cells* adjoining the inner epiderm, the *mesophyl* ground tissue consists of nearly isodiametric cells most of which contain aleurone grains (*al*) with an occasional cell containing a crystal cluster of calcium oxalate (*k*). Procambium bundles (*g*) occur in the central portion of the mesophyl, also the large lysiginous resin cavities (*s*) containing dark secretion about which are two or more layers of elongated thin-walled cells named by Hanausek "mucilage cells."

The contents of the *resin cavities* deserve special notice, as these are the subject of extensive chemical investigations. Hanausek [1] notes that in water mounts the secretion is partly in the form of a solution in which are minute dark bodies which, as the liquid emulsifies, flow out of the cavity, showing lively Brownian movements, and that concentrated sulphuric acid dissolves the secretion to a beautiful red solution while alkalis impart a green-brown color without dissolving it. Marchlewski [2] identified the substance that gives this reaction as gossypol, and Withers and Carruth [3] find that this substance renders cottonseed toxic.

The *radicle* has a well-marked periblem and plerome cylinder.

Chief Structural Characters.—Seed (12 mm.), pointed-ovoid, dark brown, anatropous, more or less hairy after ginning. Spermoderm (0.3 mm.) hard, shell-like. Perisperm and endosperm forming thin skin. Embryo bulky, cotyledons folded.

Spermoderm of thick-walled outer epidermal cells containing dark substance interspersed with hairs and stomata, subepiderm of thin-walled brown cells, colorless cells, remarkable palisade cells (150 μ), and inner brown layer. Perisperm of fringe cells. Endosperm cells containing small aleurone grains. Cotyledons with parenchyma cells

[1] Loc. cit.

[2] J. prakt. Chem. 1899, **60**, 84.

[3] J. Agr. Res. 1915, **5**, 261.

containing oil and aleurone grains and resin cavities containing a substance dissolving to a red solution in concentrated sulphuric acid.

CHEMICAL COMPOSITION.—Cottonseed yields food, feed, and fertilizer, the value of each being determined by analysis.

Relation of Ripeness to Composition.—Gallup,[1] whose analyses of cottonseed at different stages of development appear in the table below, found that just before the boll opened the fat content nearly doubled, the gossypol content increased nearly tenfold, and the ash content showed a corresponding decrease, but thereafter the constituents showed little change in amount.

Composition of Cottonseed at Different Stages of Development (Gallup)
(Results in percentages of dry matter)

	Protein	Fat	N-f. ext.	Fiber	Ash	Gossypol
	%	%	%	%	%	%
Boll about to open	28.46	13.97	32.81	18.56	6.20	0.048
Boll just open	31.11	24.01	26.49	14.46	3.93	0.428
Boll open 2 to 3 days	28.46	24.82	28.43	15.13	3.16	0.461
Boll open 5 to 6 days	29.86	23.73	27.93	15.33	3.15	0.538
Boll open over 6 days	28.37	24.41	28.69	15.20	3.33	0.546
Seeds mature	30.29	25.76	36.34	14.37	3.24	0.551
Seeds from gin	29.01	23.41	28.46	15.78	3.34	0.452

Composition of Parts (Kernels, Hulls, Linters, and Cake).—Compared with the numerous official analyses of cottonseed meal there are few analyses of the whole seed or of the kernel (decorticated seed) and hulls. Such analyses are of secondary practical importance as the whole seed is pressed locally, the hulls are run in with the ground cake, and only standardized feeds and oil enter into commerce.

Mechanical Separation of Parts.—McBryde[2] reports a series of analyses of parts of the cotton plant made by him at the South Carolina Experiment Station. He points out that the percentages of meal, oil, hulls, and linters obtained after hand shelling and pressing are somewhat different from those of mill practice, as is illustrated by the figures on the following page compiled by him from various sources.

Wesson[3] states that in the early days of the industry the kernels and hulls were considered in practice each to form half of the seed, but by

[1] J. Agr. Res. 1927, **34**, 987.
[2] Tennessee Agr. Exp. Sta. 1891, Bul. 4, No. 5.
[3] Chem. Met. Eng. 1919, **21**, No. 13; **22**, No. 10.

	Machine separated	Hand separated
	%	%
Meal	35.5	30.0
Oil	12.5	20.0
Hulls	48.9	40.0
Linters	1.1	10.0
	98.0	100.0

modern methods the yield of hulls is diminished and that of both meal and oil increased. The amount of hulls run in with the meal more than compensates for the greater amount of oil expressed by improved machinery. These points are clearly brought out by the following results representing actual factory experience during two successive years and also the products of Georgia and Texas seed:

	Mill Output		Georgia cottonseed	Texas cottonseed
	1919	1920		
	%	%	%	%
Cake	48.4	49.0	50.5	51.0
Oil	14.8	16.5	16.9	12.3
Hulls	25.2	24.5	18.8	24.7
Linters	5.1	5.0	7.7	7.2
Loss	6.5	5.0	6.1	4.8
	100.0	100.0	100.0	100.0

Harrington,[1] in the examination of the seeds of 73 varieties and strains of cottonseed belonging to 7 main groups, found a range of from 43.30 to 56.43 per cent of kernels (meats) and of from 43.67 to 56.70 per cent of hulls.

Analyses of Parts.—In analyses reported by Wesson[2] the meats (kernels) constituted 55 per cent of Georgia cottonseed and contained 36.99 per cent of protein and 37.00 per cent of fat, whereas the meats constituted 53 per cent of Texas cottonseed and contained 43.50 per cent of protein and 31.20 per cent of fat. These figures may be com-

[1] Texas Agr. Exp. Sta. 1928, Bul. **374.**

[2] Loc. cit.

pared with those for the parts of Georgia and Texas seed given above, since they represent the same lots of seeds.

McBryde [1] has compiled in the table below the results on the proximate constituents in the water-free materials. Those for the hand separations are from the Report of the North Carolina Agricultural Experiment Station for 1882. The figures for the seed, the hand separations, and the machine separations, being from different sources, are not strictly comparable with each other.

Composition of Cottonseed and Its Parts (McBryde)

(Results in percentages of dry matter)

	Seed	Hand Separated		Machine Separated	
		Kernels	Hulls	Meal	Hulls
	%	%	%	%	%
Protein	20.61	31.21	2.41	51.12	5.19
Fat	23.26	39.00	0.64	10.01	2.35
N-f. ext.	28.47	20.82	42.57	26.37	45.31
Fiber	24.13	4.67	51.87	4.90	43.85
Ash	3.53	4.30	2.51	7.60	3.30
	100.00	100.00	100.00	100.00	100.00

Harrington [2] found the following range in composition of the kernels (meats) and the hulls of 73 varieties and strains:

Composition of Cottonseed Kernels and Hulls (Harrington)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Kernels:						
Min.	5.22	50.00	23.95	0.18	1.75	4.51
Max.	7.02	55.68	35.90	10.90	2.15	5.11
Hulls:						
Min.	8.18	1.62	0.12	34.82	41.23	2.41
Max.	9.97	5.18	1.05	42.13	47.93	2.78

The wide gap between the maximum and minimum results given above for nitrogen-free extract in the kernels, due partly at least to the

[1] Loc. cit.

[2] Loc. cit.

use of the conventional factor 6.25 in the calculation of the protein, illustrates the imperfection of our methods of analysis. Were it practicable to use the correct factor (whatever it may be), the range would be narrowed and be in conformity to the true percentages. Until the proper factor is decided on and even then, if uniformity seems more desirable than accuracy in specific cases, such inconsistencies are inevitable.

The average composition of the whole seed by typical varieties appears in the table below as given by Harrington,[1] who states "the variety having the lowest percentage of hulls and the highest percentage of meats will have the greatest amount of oil, regardless of the size of the seed."

Average Composition of Whole Cottonseed (Harrington)

Variety	Weight 100 seeds	Hulls	Meats	Oil	Protein
	grams	%	%	%	%
Acala	10.45	47.37	52.63	16.65	27.55
Burnett	8.44	49.64	50.36	16.39	28.47
Cleveland	8.88	49.08	50.92	15.25	27.30
Delfos	8.65	51.92	48.08	15.19	27.82
Half and Half	9.01	45.74	54.26	17.29	29.40
Lone Star	10.65	51.13	48.87	15.87	27.85
Long Staple Average	9.19	51.06	48.94	15.43	27.61
Mebane	9.97	49.51	50.49	16.18	28.15
Rowden	11.17	51.28	48.72	15.46	27.10

Composition of Cottonseed Products. *Cottonseed Meal.*—The average composition of the cottonseed meal on the market in the last quarter of the nineteenth century was little inferior to that shown in the above analysis by McBryde. As given in Jenkins and Winton's Compilation the average of 35 analyses made prior to 1892, calculated to the water-free substances, was: protein 46.1, fat 14.2, nitrogen-free extract 25.8, fiber 6.1, and ash 7.8 per cent.

In more recent years more or less of the cottonseed hulls, a by-product formerly burned under the boilers in the oil mills, has been mixed with the meal in various proportions, thus reducing the content of protein and fat and increasing the content of fiber. This practice appears to be justified since the hulls contain a certain amount of food elements and also serve as roughage.

[1] Loc. cit.

Lindsey, Smith, and Beals, in the Compilation of Analyses made at the Massachusetts Experiment Station,[1] bring out clearly the difference in composition between the product on the market prior to 1910 and since that date.

Composition of Cottonseed Meal (Lindsey et al.)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Prior to 1910 . .	404	7.0	44.6	10.0	25.2	6.5	6.7
Since 1910	255	7.0	39.4	7.2	29.4	10.8	6.2

The term " cottonseed meal " is now restricted to a high-grade feed, although not so high as old-fashioned cottonseed meal, and the term " cottonseed feed " is applied to a lower-grade feed.

The following analyses reported by Fuller [2] and made under the direction of Fraps in the enforcement of the Texas Feed Law, which does not recognize as meal a product containing less than 43 per cent of protein, illustrates the range in composition of several types of cottonseed products:

Composition of Cottonseed Products (Fuller)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Cake, 43 per cent protein	214	6.16	43.88	6.39	27.88	10.37	5.32
Cake screenings, 43 per cent protein	2	6.11	43.03	6.74	27.69	11.26	5.17
Ground feed, 41.12 per cent protein	8	6.47	42.48	6.49	27.99	11.19	5.38
Ground feed, 38.56 per cent protein	2	6.83	45.04	7.98	25.91	8.57	5.67
Meal, 45 per cent protein	2	6.50	44.36	6.46	27.04	10.45	5.19
Meal, 43 per cent protein	603	6.29	43.04	7.27	27.44	10.61	5.35
Whole-pressed seed, 28 per cent protein	2	5.43	28.69	6.08	32.08	23.50	4.22
Whole-pressed seed, 25 per cent protein	17	5.27	28.25	6.49	32.56	23.25	4.20

[1] Spec. Bul. 1919.

[2] Texas Agr. Exp. Sta. 1929, Bul. 404.

Cottonseed Flour.—The substitution of finely ground cottonseed meal free from hulls for a portion of the flour in making bread and biscuit has been studied by Fraps.[1] He cautions against using more than one part of cotton seed flour to four parts of wheat flour and overeating, because of its possible injurious properties. The composition of the cottonseed flour and bread products are tabulated as follows:

Composition of Cottonseed Flour and Bakery Products (Fraps)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Cottonseed:						
Flour	7.21	48.25	12.16	22.85	3.95	5.58
Bread	24.98	14.13	4.85	51.98	1.95	2.11
Steamed bread	40.00	13.48	7.80	33.59	2.13	3.00
Ginger bread	22.80	17.19	11.63	42.98	2.60	2.80
Ginger snaps	6.50	16.32	14.70	57.64	2.71	2.13
Biscuits	11.23	18.52	11.42	51.53	3.05	4.25

Proteins.—Both Ritthausen [2] and Osborne and Voorhees[3] undertook to separate the proteins from cottonseed, but the results were far from complete owing to imperfect filtration, interfering coloring substances, and other difficulties. In one case only, namely *edestin*, a globulin (soluble in salt solution), was a protein isolated in considerable amount and in a state of purity. The protein soluble in water was mostly *proteose*.

The percentages by Osborne and Voorhees given below represent the protein dissolved by the usual solvents:

	Protein in fat-free kernels	Nitrogen in total nitrogen of kernel
	%	%
Soluble in water	0.75	2.0
Soluble in salt solution	15.83	42.3
Soluble in alkali	17.00	44.3
Insoluble in alkali	4.27	11.4
	37.85	100.0

[1] Texas Agr. Exp. Sta. 1910, Bul. **128.**
[2] J. prakt. Chem. 1881, **23,** 481.
[3] J. Am. Chem. Soc. 1894, **16,** 778.

Jones and Csonka [1] by preliminary extraction with benzol were able to remove most of the oil, resins, and coloring matter from the kernel. They obtained two proteins, α-globulin and β-globulin, by precipitation from the salt solution extract with ammonium sulphate added to 0.4 to 0.5 and 0.7 to 0.8 saturation respectively, the latter case after previous dilution of the extract. The yield of α-globulin was 2.59 per cent and its coagulation point 95 to 97° C.; the yield of β-globulin was 16.0 per cent and its coagulation point 92 to 93° C. They also isolated 2.08 per cent of a pentose protein by evaporating *in vacuo* the filtrate from the dialyzed globulins and precipitation with alcohol. Analysis showed that the pentose protein contained pentose 16.57, phosphorus 0.194, and nitrogen 12.64 per cent. A small amount of what appeared to be a *glutelin* was isolated. No nucleic acid was found.

The *Ultimate Composition* of Osborne and Voorhees' *edestin,* which is practically identical with the edestin of squash seed, linseed, and castor bean, follows:

	%
Carbon	51.71
Hydrogen	6.86
Nitrogen	18.64
Sulphur	0.62
Oxygen	22.17
	100.00

Amino Acids of Cottonseed Proteins.—Abderhalden and Rostoski [2] obtained results by hydrolysis of the edestin as tabulated below:

	%
Glycocoll	1.2
Alanine	4.5
Valine	+
Leucine	15.5
Serine	0.4
Aspartic acid	2.9
Glutamic acid	17.2
Tyrosine	2.3
Phenylalanine	3.9
Proline	2.3
Tryptophane	+
	50.2

[1] J. Biol. Chem. 1925, **64**, 673.
[2] Z. physiol. Chem. 1905, **44**, 265.

Jones, Gersdorff, and Moeller[1] report in cottonseed *globulin*: cystine 1.07 and tryptophane 2.58 per cent.

Nitrogen Distribution in Cottonseed Proteins.—Jones and Csonka[2] by Van Slyke's method found the nitrogen distribution in α- and β-globulin and the pentose protein to be as follows:

NITROGEN DISTRIBUTION IN COTTONSEED PROTEINS (JONES AND CSONKA)

	α-Globulin	β-Globulin	Pentose Protein
	%	%	%
Humin N	1.66	1.87	4.62
Cystine N	0.54	0.51	1.43
Arginine N	22.90	23.94	23.02
Lysine N	4.07	4.36	8.54
Histidine N	5.27	6.15	3.09
Amino N in filtrate	51.53	50.11	43.93
Non-amino N in filtrate	2.58	1.90	1.03
Amide N	11.40	11.70	12.99
	99.95	100.54	98.65

Nitrogen Distribution in Cottonseed Meal.—In 1915, Grindley, Joseph, and Slater[3] and Nollau[4] reported results by Van Slyke's method on the nitrogen distribution in cottonseed meal. The lack of concordance in some of the results may be explained as due in part to differences in the material and in part to imperfections of the method. In the table below the results by Nollau are those obtained in 1915; those by Hamilton, Nevens, and Grindley[5] represent the status of the method six years later.

Nitrogenous Bases.—Ritthausen and Weger[6] found *betaine* in the mother liquor from the raffinose. Böhm[7] showed that *choline* was also present.

Oil.—The percentages of oil in the seed, the yield of oil, and the percentages left in the cake and meal are considered in the general statements on composition.

Physical and Chemical Values are frequently determined in distinguishing cottonseed oil from olive oil for which it has been substituted. The range for cottonseed oil, as of other oils and fats, has been based on determinations in samples often not well authenticated, hence the dis-

[1] J. Biol. Chem. 1924, **62**, 183.
[2] Loc. cit.
[3] J. Am. Chem. Soc. **37**, 1778.
[4] J. Biol. Chem. **21**, 611.
[5] J. Biol. Chem. 1921, **48**, 249.
[6] J. prakt. Chem. 2 ser. **30**, 32.
[7] Arch. exp. Path. **19**, 60.

NITROGEN DISTRIBUTION IN COTTONSEED MEAL

	Nollau	Hamilton, Nevens and Grindley
	%	%
Humin N	6.27	6.30
Cystine N	2.74	0.94
Arginine N	12.77	18.71
Histidine N	7.57	7.17
Lysine N	1.94	4.21
Mono-amino N*	45.02	40.72
Non-amino N *	7.49	2.87
Ether soluble N	.....	0.10
Alcohol soluble N	.....	0.55
Non-protein N †	.....	5.56
Amide N	14.06	9.41
N lost in analysis	.....	3.29
	97.86	99.83

* In filtrate from bases. Includes proline, oxyproline, and tryptophane N.
† Soluble in 1 per cent trichloracetic acid—in filtrate from colloidal iron.

crepancies in the literature. The following limits appear to be justified by results obtained by De Negri and Fabris,[1] Tolman and Munson,[2] and others, including the writers:

VALUES FOR COTTONSEED OIL

	Sp. gr. 15.5° C.	Refractive index 25° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer
						° C.
Min.	0.922	1.470	50	191	104	34
Max.	0.925	1.472	78	195	114	40

Composition of Cottonseed Oil.—Hazura[3] established the presence of linolic and oleic acids and the absence of linolenic acid in cottonseed oil. He estimated that approximately 60 per cent of linolic and 40 per cent of oleic acids were present in the unsaturated acids. Lewkowitsch[4]

[1] Ann. Lab. chim. centr. Gabelle, **2**, Gli Olii, II, 92.
[2] U. S. Dept. Agr., Bur. Chem. 1903, Bul. **77**.
[3] Z. angew. Chem. 1888, 315.
[4] Chem. Tech. Anal. Oils, etc. London, 1913, **1**, 573.

gives Farnsteiner's figure for linolic acid, namely 23.9 per cent, found in direct experiment. These conflicting statements led Jamieson and Baughman[1] to an investigation of American oil, cold pressed by an expeller, derived from Sea Island cotton. Later[2] they applied the same method to the oil of upland cottonseed. By the lead salt ether method they found in the Sea Island oil 23 per cent of saturated and 72.5 per cent of unsaturated acids. Examination of the latter gave: iodine number (Hanus) 142.2, saponification number 199.4, and mean molecular weight 281.3.

Composition of Cottonseed Oil (Jamieson and Baughman)

	Upland cottonseed	Sea Island cottonseed
	%	%
Glycerides of:		
Arachidic acid	0.1	0.6
Stearic acid	1.9	2.0
Palmitic acid	21.9	20.0
Myristic acid	0.5	0.3
Oleic acid	30.5	35.2
Linolic acid	44.8	41.7
Unsaponifiable matter	0.9	
	100.6	99.8

Qualitative Reactions.—The Becchi test, depending on reduction of silver from a silver nitrate solution, variously carried out, is characteristic to a limited extent.

A more valuable test is that proposed by Halphen in which equal volumes of the oil and the reagent (a mixture of one part of a 1 per cent solution of sulphur in carbon disulphide and one part of amyl alcohol) are heated for 15 minutes in a boiling brine bath. The characteristic deep red color thus formed has been shown by Gastaldi[3] to be due to the action of pyridin bases present as impurities in the amyl alcohol on a chromogenic constituent of the oil. This substance passes into the fat of animals fed on cottonseed meal; on the other hand it may be destroyed in the oil by heating and various treatments. Kapok oil and other oils of the *Bombaceæ* give the same reaction.

Phytosterol.—According to Anderson and Moore,[4] at least two phy-

[1] J. Am. Chem. Soc. 1920, **42**, 1197.
[2] Oil Fat Ind. 1927, **4**, 131.
[3] Chem. Z. 1911, **35**, 688.
[4] J. Am. Chem. Soc. 1923, **45**, 1944.

tosterols occur in cottonseed oil. Fractions separated by crystallization had the following characteristics: melting point 138 to 139° and 134 to 135° C., optical rotation −34.19° and −33.61°. The authors state that probably neither preparation was homogeneous, as complete separation was difficult if not impossible.

Carbohydrates.—Ritthausen [1] found in cottonseed a crystalline carbohydrate to which he gave the name *gossypose*. Tollens [2] proved that this sugar was identical with the *melitose* of Berthelot and the *raffinose* of Loiseau. The latter name was adopted. See Browne's "Sugar Analysis," New York, 1912, p. 732.

Pentosans.—See Sea Island Cottonseed.

Xylose.—Markley [3] gives unusually complete analyses of "cottonseed hull bran" showing a yield of xylose and other pentoses amounting to about 40 per cent and furfural to 22.28 per cent. Enley [4] has developed a process for production of xylose from cottonseed hulls on a large scale.

Gossypol.—Although previous investigators had obtained extracts containing the toxic principle of cottonseed meal, Marchlewski [5] appears to have been the first to separate the substance from its impurities and obtain crystals which according to Carruth must have been the acetate.

Crawford [6] believed that the chief toxic substance of cottonseed meal is a salt of pyrophosphoric acid formed by the heating at a high temperature incident to the process of manufacture.

Withers and Ray [7] in a preliminary report stated that by extracting with gasoline, boiling with an alcoholic solution of sodium hydroxide, and filtering they were able to remove the toxic substance from cottonseed meal.

Withers and Carruth [8] separated from cottonseed kernels a toxic substance apparently identical with the gossypol of Marchlewski. The substance is quickly oxidized and made harmless by heating in an alcoholic sodium hydroxide solution.

Carruth,[9] adhering to Marchlewski's name gossypol, gossyp(iumphen)ol, distinguishes between the phenolic body itself (gossypol) and gossypol acetate, which he showed is the substance Marchlewski obtained in crystalline form. The red color which appears on adding concentrated sulphuric acid to the contents of the resin cavities in microtests is regarded by Carruth as a gossypol reaction.

[1] J. prakt. Chem. 2 ser. **29**, 351.
[2] B. deut. chem. Ges. 1885, **18**, 26.
[3] J. Am. Soc. Agron. 1928, **20**, 1102.
[4] Science 1930, **71**, lvi.
[5] J. prakt. Chem. 1899, **60**, 84.
[6] J. Pharmacol. 1910, **1**, 519.
[7] Science 1912, **36**, 31.
[8] Science 1915, **41**, 324.
[9] J. Am. Chem. Soc. 1918, **40**, 647.

He found in the undried kernels as high as 0.63 per cent of gossypol, and his ultimate analyses indicate an empirical formula of $C_{30}H_{28}O_9$ or $C_{30}H_{30}O_9$, although its constitution is unknown.

Carruth also isolated three substances more or less resembling gossypol, namely *a*-, *b*-, *c*-, and *d*-gossypol, the last being the less soluble and less toxic substance into which gossypol appears to pass on proper cooking. Very little gossypol was found in hot-pressed meal or oil, but at least three-fourths appeared in the oil obtained by commercial "cold pressing," even though considerable heat develops during the process. In true cold-pressed oil little gossypol is present because the oil is squeezed out before it can penetrate into the resin cavities.

Commercial "cold-pressed" oil contains as high as 1.5 per cent of gossypol, which on treatment with alkali as is customary in refining passes into the foots, leaving the oil itself entirely free from the toxic substances.

In the determination of gossypol Carruth made use of the very slightly soluble dianiline salt, a compound discovered by Dobbins of the same laboratory, which separates from an oily extract on standing as orange-yellow microscopic crystals.

Withers and Carruth [1] in experiments with rats and pigs established the toxicity of gossypol. They found that cottonseed meal is much less toxic than raw cottonseed, owing mainly to the oxidation of the gossypol during cooking. Nevertheless it was found to be injurious to pigs. Raw seed, extracted with ether, was not injurious.

Withers,[2] in continuation of the study, was able to obtain meal free from gossypol and *d*-gossypol by extraction with ether and then with aniline. Aniline-*d*-gossypol contained 1.07 per cent more carbon and 0.36 per cent more hydrogen than aniline-gossypol, but the nitrogen in the two substances was about the same. The greater gain in weight at 140° C. of the aniline-gossypol is regarded as further evidence that the two substances are not the same. In cotton hulls he found 0.75 per cent and in the meats 0.7 per cent of gossypol.

Relation of Gossypol Content to Development.—Analyses (shown below) were made by Gallup [3] of cottonseed of the variety Oklahoma Triumph 44 at different stages of development. Gossypol was determined by Carruth's method as modified by Schwartze and Alsberg, using the factor 0.74 for the conversion of the aniline gossypol, which approaches $C_{30}H_{28}O_9 2C_6H_5NH_2$ in composition, into gossypol.

[1] J. Agr. Res. 1918, **12**, 83.
[2] N. Carolina Agr. Exp. Sta. Rep. 1919, p. 40.
[3] J. Agr. Res. 1927, **34**, 987.

Analyses Showing Gossypol Content of Cottonseed at Different Stages of Maturity (Gallup)

(Dry basis)

Condition of boll or seeds	Protein	Fat	N-f.ext.	Fiber	Ash	Gossypol
	%	%	%	%	%	%
About to open	28.46	13.97	32.81	18.56	6.20	0.048
Just open	31.11	24.01	26.49	14.46	3.93	0.428
Open 2 to 3 days	28.46	24.82	28.43	15.13	3.16	0.461
Open 5 to 6 days	29.86	23.73	27.93	15.33	3.15	0.538
Open over 6 days	28.37	24.41	28.69	15.20	3.33	0.546
Mature seeds picked Feb. 1	30.29	25.76	26.34	14.37	3.24	0.551
Seeds obtained from gin	29.01	23.41	28.46	15.78	3.34	0.452

Relation of Gossypol Content to Fat Content.—Schwartze and Alsberg [1] report a range in gossypol content of cottonseed kernels (decorticated seeds) of 0.4 to 1.2 per cent and show that this is independent of variety but bears a striking relation to the fat content. For example, the sample with the lowest fat content (28.87 per cent) contained only 0.411 per cent of gossypol, whereas the sample with the highest fat content (40.98 per cent) contained 0.957 per cent of gosspyol, the water content in the two samples agreeing within 1 per cent.

Gallup (see table above) found no correlation between the formation of oil and the formation of gossypol.

Influence of Process on Gossypol Content.—Examination by Sherwood [2] of three types of cottonseed meal for gossypol and *d*-gossypol gave the maximum and minimum results shown in the table. The continuous cooker meals were from North Carolina.

Process	Samples	Gossypol	*d*-Gossypol
		%	%
Continuous cooker	22	0.007–0.228	0.633–1.076
Open kettle	14	0.021–0.150	0.544–0.963
Cold pressed	4	0.020–0.102	0.335–0.505

He concludes that 70 per cent or more of the gossypol originally present is converted in the manufacturing process into the less toxic *d*-gossypol.

[1] J. Agr. Res. 1923, **25**, 285.

[2] Ibid. 1926, **32**, 793.

In experiments on the destruction of toxic substances Gallup[1] tested the efficiency of (1) dry heating of the ground seed at 110° and (2) autoclaving the whole seed wet at 20 lb. pressure with the following results:

	Gossypol	*d*-Gossypol
Original seed	0.275	none
Ground seed heated dry at 110° C.:		
10 minutes	0.137	0.135
15 minutes	0.021	0.309
30 minutes	0.021	0.222
.....	.....	.....
16 hours	none	0.112
Whole seed autoclaved at 20 pounds:		
10 minutes	0.082	0.091
20 minutes	0.058	0.075
1 hour	none	0.048
2 hours	none	none

Rats fed on meal heated at 110° C. for 1 hour died in 30 days; those fed on whole seed autoclaved wet for 30 minutes were living after 100 days. All the rats fed on untreated seed or sprouted seed died in 40 days. These experiments indicate that both gossypol and *d*-gossypol are toxic.

Clark[2] believes that the cooking process does not alter the gossypol molecule and the term *d*-gossypol should be abandoned. He advances the hypothesis that the gossypol merely condenses with the free amino groups of the protein forming insoluble and non-toxic substances. From both gossypol and *d*-gosspol he prepared crystalline dianiline gossypol identical in all respects.

Phosphorus-Organic Compounds.—Rather[3] found that about 25 per cent of the total phosphorus of cottonseed meal was soluble in 0.2 per cent of hydrochloric acid, which is much less than the amounts of water-soluble phosphorus given by other authors. The form in which this phosphorus existed was not ascertained, although it was shown that meta- and pyro-phosphoric acids were absent.

Anderson[4] demonstrated that cottonseed meal contains an organic phosphoric acid similar to phytic acid. It gave all the reactions pre-

[1] Ind. Eng. Chem. 1927, **19**, 726.
[2] J. Biol. Chem. 1928, **76**, 229.
[3] Texas Agr. Exp. Sta. 1912, Bul. **146**.
[4] New York Agr. Exp. Sta. 1912, Tech. Bul. **25**; J. Biol. Chem. 1912, **13**, 311.

viously attributed to pyro- and meta-phosphoric acids. Its identity with phytin was not established, but it was shown to yield inosite and phosphoric acid on heating in a closed tube with dilute sulphuric acid.

In a later paper[1] Anderson describes the barium and silver salts and states his belief that phytin is inosite hexaphosphate ($C_6H_{18}O_{24}P_6$) or an isomer.

Mineral Constituents.—McBryde[2] determined the principal ash constituents of whole cottonseed, kernels, and hulls.

Analysis of Cottonseed Ash (McBryde)

(Percentages of the dry matter)

	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	Sand
	%	%	%	%	%	%	%
Whole seed	1.255	0.021	0.201	0.537	1.096	0.138	0.025
Kernels	1.216	.....	0.175	0.883	1.840	0.126	0.580
Hulls	1.454	.....	0.182	0.390	0.102	0.105	0.042

McHargue[3] determined the inorganic elements, including the rarer metals, in the leaves, stalks, kernels, and hulls of the cotton plant. Only the figures obtained on the kernels and hulls, which contained in the water-free material 4.18 and 2.68 per cent of ash and 47.00 and 3.88 per cent of protein respectively, are included in the following tabular statement:

Mineral Constituents of Cottonseed Kernels and Hulls (McHargue)

(Percentages of the dry matter)

	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	P	S
	%	%	%	%	%	%	%	%	%	%
Kernels	1.159	0.711	0.186	0.378	0.0150	0.0013	0.0054	0.032	1.794	0.361
Hulls	1.143	0.877	0.137	0.130	0.0248	0.0138	0.0014	0.002	0.058	0.038

The author himself calls attention to the high percentages of sodium in the ash but was unable to explain the same as the crop was not grown under his supervision and he had no knowledge of the nature of the soil or the fertilizer used.

[1] New York Agr. Exp. Sta. 1914, Tech. Bul. **32**; J. Biol. Chem. 1914, **17**, 141.

[2] Tennesee Agr. Exp. Sta. 1891, Bul. **4**, 5.

[3] J. Am. Soc. Agron. 1926, **18**, 1076.

SEA ISLAND COTTONSEED

Gossypium Barbadense L.

This species, also known as Barbadoes, Egyptian, and long-staple cotton, is a native of the West Indies. It is distinguished from common cotton by its somewhat higher growth (2 meters or over), its longer fibers, and the absence of short fibers remaining on the seed after ginning. It is extensively grown in the lowlands of South Carolina and neighboring regions, and the fiber is used in fine thread and textiles.

MACROSCOPIC STRUCTURE.—The *seed* is naked, nearly black, not covered with a mat of short fibers, and, as brought to notice by Richardson of Lincoln, England, the inner surface of the hull is deep brown, not as in common cotton more or less opalescent.

MICROSCOPIC STRUCTURE.—The *outer* and *inner brown coats* of the spermoderm are of a darker color than the corresponding layers of common cottonseed and the innermost tissue is not, as in common cotton, more or less disorganized and without brown contents.

In other respects upland and Sea Island cotton are alike in structure.

CHEMICAL COMPOSITION.—Shiver [1] analyzed 2 varieties of Sea Island cottonseed and its products as secured by the processes in use in 1902. As the seeds of the 2 varieties were practically the same in composition, except as regards the fat content which was nearly 2 per cent more in one variety than the other, only the average results are herewith given. The kernels constituted 59.58 per cent and the hulls 40.42 per cent of the seed.

Average Composition of Sea Island Cottonseed and Its Products (Shiver)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Seed	8.05	20.96	19.71	31.44	15.31	4.53
Kernels	6.47	34.00	34.65	16.80*	2.31	5.77
Meal	9.24	28.43	7.86	33.41†	15.92	5.14
Hulls	10.29	6.71	3.04	44.73	32.22	3.01
Linters	6.93	3.88	2.27	11.29	73.20	2.43
Lint	5.91	2.30	1.10	8.03	81.04	1.62

* Pentosans 4.49 per cent. † Pentosans 13.08 per cent.

Proteins.—See Cottonseed.

Oil.—According to Shiver [2] the mill yield of oil was 75.8 per cent of

[1] S. Carolina Agr. Exp. Sta. 1902, Bul. 68, 90.

[2] Loc. cit.

the total amount present in the seed. At 23.6° C. the refractive index of the oil was 1.4718 and the saponification equivalent 215.

Composition.—See Cottonseed.

Carbohydrates.—See Cottonseed.

Pentosans.—Shiver [1] found 4.49 per cent of pentosans in Sea Island cottonseed kernels and 13.08 per cent in the meal. Obviously the meal contained considerable hulls.

Xylose.—See Cottonseed.

Mineral Constituents.—The composition of the ash was determined by Shiver [1] from the standpoint of fertilizing value, hence the determinations of soluble and insoluble phosphoric acid and water-soluble potash. The results of these determinations are, however, of general interest, especially as the figures bear relation to the phytin content.

Constituents of Ash of Sea Island Cottonseed and Its Products (Shiver)

	Seed	Kernels	Meal	Hulls	Linter	Lint
	%	%	%	%	%	%
Ash	4.530	5.770	5.140	3.010	2.430	1.62
Constituents of ash:						
Total potash	1.615	1.734	1.676	1.346	0.510	0.57
Water-soluble potash	1.370	1.560	1.370	1.090		
Lime	0.322	0.374	0.346	0.239	0.212	0.17
Magnesia	0.657	0.905	0.837	0.331	0.158	0.13
Total phosphoric acid	1.628	2.676	1.894	0.387	0.198	0.13
Insoluble phosphoric acid	0.080	0.120	0.140	0.050		
Soluble phosphoric acid	1.360	1.660	1.360	0.330		
Reverted phosphoric acid	0.180	0.900	0.400	0.010		
Insoluble matter	0.037	0.050	0.063	0.051	0.939	0.14

[1] Loc. cit.

SEEDS OF THE BOMBAX FAMILY

(*Bombacaceæ*)

Species known as kapok are grouped in this family, which is closely related to the mallow family, to which cotton belongs. The cotyledons, unlike those of cottonseed, do not contain resin cavities.

JAVANESE KAPOK SEED

Eriodendron anfractuosum D.C. = *Ceiba pentandra* (L.) Gärtn. = *Bombax pentandrum* L.

Fr. Kapok. Sp. Pochote. It. Kapok. Ger. Kapoksamen.

Both Javanese kapok and the East Indian species (*Bombax Ceiba* L. = *B. malabaricum* D.C.) yield coarse fibers used in upholstery. These fibers are borne on the endocarp and not, as in the case of cotton, a related plant, on the outer epiderm of the spermoderm. Of chief importance is Javanese kapok, the product of a tree grown in various tropical regions of the Old and New World. It is said that the seed is eaten by the native Polynesians, but its chief use is for oil production both in the countries of origin and to some extent in Holland.[1]

MACROSCOPIC STRUCTURE.—In the five-celled *fruit* are borne the naked *seeds*, which are about the size of a pea. They are characterized by a prominent protuberance which Von Bretfeld [2] considers to be funiculus. In any event, hilum and micropyle are in close proximity in this region. As in cottonseed the cotyledons are much folded but not so tightly. Of special importance is the absence of resin cavities such as in cottonseed appear as black spots under a lens.

MICROSCOPIC STRUCTURE.—Von Bretfeld emphasizes the following distinctions from cotton: (1) the *outer epiderm* has thin walls and is without hairs but here and there with depressions formed by the abrupt decrease in height of the cells, (2) the *colorless cells* form two to four cell rows and contain crystal clusters, (3) the *palisade cells* are one-third shorter, (4) the inner *brown layer* has fewer "star-shaped" cells, (5) the *perisperm* cells are larger and less knotty, and (6) *resin cavities* are lacking in the cotyledons.

[1] Van Pesch: Landw. Vers.-Stat. 1896, **47**, 471.

[2] J. Landw. 1887, **35**, 29.

CHIEF STRUCTURAL CHARACTERS.—Seed without hairs but with protuberance.

Colorless cells containing crystal clusters in several rows; palisade cells shorter than in cottonseed. Cotyledons without resin cavities.

CHEMICAL COMPOSITION.—The absence of resin cavities in both Javanese and East Indian kapok at once suggests the possible absence of gossypol or allied toxic substances, but no experimental evidence is at hand on that important point.

Sprinkmeyer and Diedrichs [1] call attention to the difference in size of common and Ecuador seed, the common being 5 mm. long, the Ecuador 8 mm., but in both the ratio of shell to kernels is about 42 : 58. The common seed contained protein 25 to 33 per cent, fat 25 to 28, and ash 5.4 to 5.6; the Ecuador, protein 35.2, fat 21.6, and ash 6.05 per cent, all on the dry basis.

Matthes and Holtz [2] state that the air-dry seed contains 25.6 per cent of fat, which is not clear until heated to 28 to 29°.

Georgi [3] found by chloroform extraction over 20 per cent of fatty oil which deposits stearin on standing. The cake contained 3.98 per cent of nitrogen.

Oil. *Physical and Chemical Values.*—Data on the composition of the seed and oil although not meager are conflicting. Lewkowitsch

VALUES OF JAVANESE KAPOK SEED OIL

	Sp. gr. at 15°C.	Refractive index at 40°C.	Saponification No.	Iodine No.	Acid No.	Fatty acids, titer	Unsaponifiable matter
						°C.	%
Sprinkmeyer and Diedrichs:							
Min.	0.9235	1.4591*	189.2	85.0	.....	27.0	
Max.	0.9326	1.4657*	196.8	91.0	.....	32.0	
Matthes and Holtz:							
Extracted oil	0.9198	.....	196.3	93.9	4.0	34.5‡	
Expressed oil	0.9218	1.4630	192.3	88.7	21.6		
Dickhart and Trevithick	0.9221	1.4636*	194.5	94.9	12.1†	28.1	0.66
Georgi	0.9183	1.4636*	191.0	94.3	1.8†	28.4‡	0.8

* Recalculated for uniformity. † Per cent. ‡ Melting point.

[1] Z. Unters. Nahr.-Genussm. 1913, **26**, 86.

[2] Arch. Pharm. 1913, **251**, 376.

[3] Malay. Agr. J. 1922, **10**, 284.

noted this in the fifth edition of his work and dropped certain figures. He does, however, give results for iodine number by three chemists as ranging from 117.9 to 129, which are 20 to over 30 points above the more recent figures given herewith. It must be admitted, however, that the higher figures are in closer agreement with those of the oil of the related species, cottonseed.

Sprinkmeyer and Diedrichs [1] give the Reichert-Meissl number as 0.20 to 0.66 and state that the oil shows a stronger Halphen reaction than cottonseed oil. Matthes and Holtz [2] found the Reichert-Meissl number to be 9.8 and the Polenske number 0.14 to 0.34. They state that the principal constituents are tri-glycerides of palmitic, oleic, and linolic acids, and that the oil is non-drying. They and Dickhart and Trevithick [3] note that the Halphen reaction is strong.

Pochote Oil.—Attention is directed by Lomanitz [4] to this oil-producing shrub now being grown on an industrial scale in Mexico. He gives two synonyms, *E. occidentale* and *E. æsculifolium*, without authorities, but obviously the shrub is not the common kapok, which is a large tree. Not finding any mention of the oil in the literature he reports the following results (and others): specific gravity at 15.5° C. 0.9253, saponification number 192, iodine number 85.89, Reichert-Meissl number 1.5, Hehner number 95.1, acetyl number 42.68, melting point of insoluble fatty acids 34.0° C., solidifying point of fatty acids (titer) 28.7° C., iodine number of insoluble fatty acids 90.31, and acid number 43.58.

EAST INDIAN KAPOK SEED

Bombax Ceiba L. = *B. malabaricum* D.C.

This species grows in the region extending from India to northern Australia.

MACROSCOPIC STRUCTURE.—Sprinkmeyer and Diedrichs [5] note the absence of a distinct protuberance on the *seed*, thus distinguishing it from Javanese kapok seed.

MICROSCOPIC STRUCTURE.—Hanausek [6] describes briefly the histology, stating that it resembles closely that of the Javanese seed.

CHEMICAL COMPOSITION.—An article published in the Bulletin of the Imperial Institute [7] states that an Indian sample examined

[1] Loc. cit.
[2] Loc. cit.
[3] Am. J. Pharm. 1922, **94**, 34.
[4] J. Ind. Eng. Chem. 1912, **4**, 625.
[5] Z. Unters. Nahr.-Genussm., 1913, **26**, 86.
[6] Tech. Mikroskopie. Stuttgart, 1901, p. 368.
[7] 1920, **18**, 335; Abs. Chem. Abs. 1921, **15**, 2007.

contained: water 8.9 and petroleum ether extract 22.3 per cent. The residual cake contained: water 11.4, protein 36.5, fat 0.8, nitrogen-free extract 24.7, fiber 19.9, and ash 6.7 per cent.

Oil. *Physical and Chemical Values.*—Sprinkmeyer and Diedrichs [1] report:

	Sp. gr. 15° C.	Refrac. index 40° C.	Saponification No.	Iodine No.	Hehner No.	Fatty acids, titer	Acid No.	Free acid as oleic
						° C.		%
Expressed.....	0.9300	1.4639	194.3	73.59	95.61	.....	3.0	0.85
Extracted.....	0.9264	1.4621	196.8	74.51	95.55	39	38.9	10.97

The following values are given for the Indian sample mentioned above: specific gravity at 15° C. 0.9208, refractive index at 40° C. 1.461, saponification number 193.3, iodine number 78, acid number 9.3, solidifying point of fatty acids 38° C., soluble volatile acids none, insoluble volatile acids 0.5 per cent, and unsaponifiable matter 1.0 per cent.

[1] Loc. cit.

NUTS OF THE LECYTHIA FAMILY

(*Lecythidaceæ*)

Several trees of this family yield large seeds with a hard shell and reserve material in the greatly enlarged radicle. The Brazil nut (*Bertholletia nobilis* Miers) and the paradise nut (*Lecythis zabucayo* Aubl.) are produced in Brazil in large quantities. Both agree in general structure and composition, the slight differences being recorded on the following pages.

BRAZIL NUT

Bertholletia nobilis Miers.

Fr. Noix du Brésil. Sp. Nuez de Brazil. It. Noce del Brasile. Ger. Paranuss.

Para nut and castaña nut—the latter a misnomer—are other names for this species. According to Young,[1] *B. nobilis* Miers not *B. excelsa* Humb. et Bonol., as formerly believed, yields the nut of commerce, although the nuts of other species are of edible quality.

The large tree grows along the rivers of Brazil, producing large quantities of nuts for table use and for oil. As the nuts are gathered during the northern spring they deteriorate if kept until the northern winter.

MACROSCOPIC STRUCTURE (Fig. 225, II).—*Nuts* of this genus are true seeds borne in a hollow, dry fruit with a hard endocarp, closely resembling that of a cocoanut, provided at the tip with a small opening and operculum. The ovary is four-celled with two rows of ovules in each cell borne on central placentæ. On ripening, the division walls break down, but their position is still indicated by ridges on the inner surface of the shell. The nut is gray-brown, transversely wrinkled. Owing to crowding it is commonly triangular, the surfaces in contact with each other being flat while that next to the shell is rounded. The raphe extends through the inner edge to the tip where two main branches extend down through the two outer edges. Both raphe and main branches send off numerous fine branchlets at an angle.

A cross section shows that the shell (*S*) has an outer light and an inner dark coat. At the angles the inner coat is broadened to a triangular tissue containing the raphe (*R*) or its main branches with accompanying

[1] Pomona J. Econ. Bot. 1911, **1** (3), 122.

tissues. The endosperm is thin. Characteristic of the group is the white oily radicle (*Ra*), forming the bulk of the seed, the cotyledons being so minute as ordinarily to escape notice.

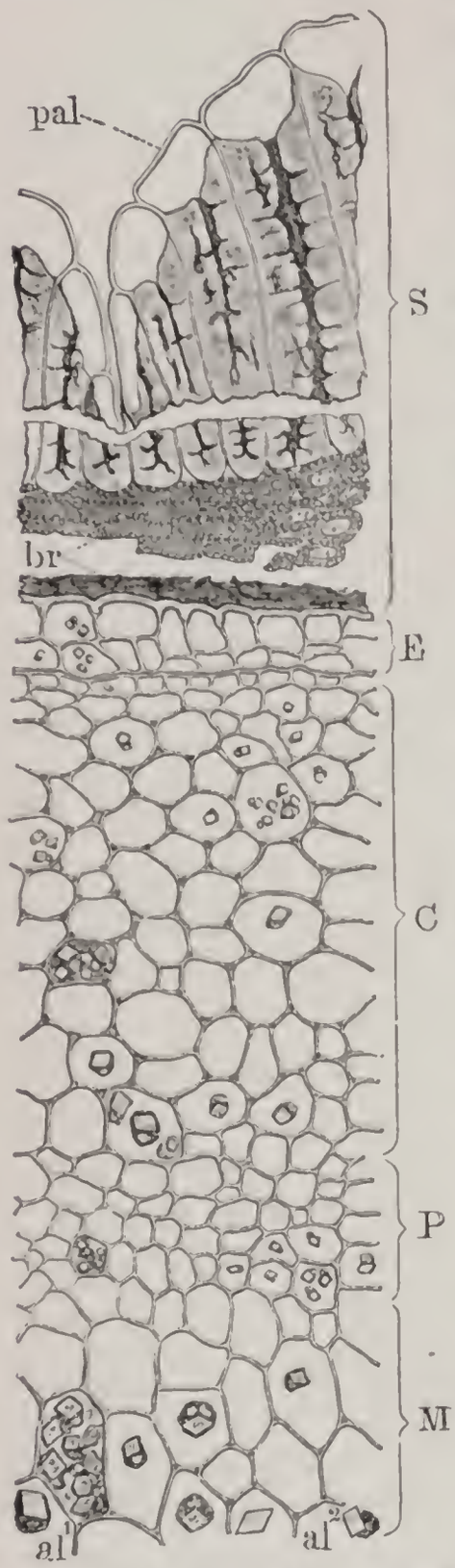


FIG. 236.—Brazil Nut. Cross section. *S* spermoderm: *pal* palisade cells, *br* brown layer. *E* endosperm. Radicle: *C*, cortex, *P* procambium tissue, *M* pith, *al*¹ aleurone grains in turpentine, *al*² aleurone grains in water. ×160. (A.L.W.)

MICROSCOPIC STRUCTURE (Fig. 236). **Spermoderm** (*S*).—Two coats are present: (1) colorless *palisade cells* (*pal*) up to 1 mm. or more high, with lumen narrow below and expanded at the outer end, and (2) *brown cells* (*br*)—the color being due to cell contents—through which at the angles run the raphe and its branches.

The walls of the *palisade cells* are pierced by numerous irregular branches of the lumen.

In the outer layers the *brown cells* have moderately thick porous walls. Over the raphe bundles at the angles the cell walls are strongly thickened and colorless, contrasting strongly with the deep brown contents.

Numerous spiral vessels, up to 15 μ broad, with one or two strands, characterize the *fibro-vascular bundles*.

Endosperm (*E*).—Two to three layers of cells with small aleurone grains form the endosperm. The outer walls and outer end of the radial walls are thickened.

Radicle.—Three well-marked zones, all containing aleurone grains and fat, are evident in cross section: (1) *cortex* (*C*) of rounded cells and small intercellular spaces, (2) *procambium zone* (*P*) of small polygonal cells, and (3) *pith* (*M*) of large polygonal cells.

The *aleurone grains* (*al*,[1] *al*[2]) of the Brazil nut are among the most striking recorded. They are largest in the pith (up to over 30 μ), smallest in the procambium zone. In sections mounted in turpentine or in glycerin-iodine after extraction with ether, the ground substance, a sharply defined crystalloid, and one or more globoids are clearly seen.

CHIEF STRUCTURAL CHARACTERS.—Nut more or less triangular, wrinkled. Spermoderm with light outer and brown inner coats; raphe tissues at angles. Embryo largely fleshy radicle.

Spermoderm of palisade cells (1 mm. or more) with lumen narrow below and expanded at outer end, and brown cells with sclerenchymatized walls in outer layers. Radicle made up of cortex, procambium, and pith; aleurone grains (30 μ) with ground substance, crystalloid, and globoids.

CHEMICAL COMPOSITION.—Analyses of the kernel by Woods and Merrill [1] and Jaffa [2] of nuts shipped to the United States from Brazil, show an exceptionally high content of fat plus protein and a correspondingly low content of carbohydrates. Results on protein and fat by Kühl [3] are somewhat lower but this may be due to a higher water content.

Composition of Brazil Nuts

	Refuse (shell)	Water	Protein	Fat	N-f.ext.	Fiber	Ash
	%	%	%	%	%	%	%
Woods and Merrill:							
Kernel	(49.6)	5.3	17.0	66.8	7.0		3.9
Whole nut	49.6	2.7	8.6	33.6	3.5		2.0
Jaffa:							
Kernel	(49.4)	4.7	17.4	65.0	5.7	3.9	3.3
Kühl:							
Kernel	.....	.....	16.2	62.7			

Brazil Nut Shell.—An analysis of the shell, made by Winton, Ogden, and Mitchell [4] at a time when ground nut shells were extensively employed for diluting spices, follows:

	%
Water	9.08
Protein (N × 6.25)	4.19
Ether extract, volatile	0.07
Ether extract, non-volatile	0.57
Alcohol extract	1.01
Reducing matters *	12.96
Starch by diastase	0.73
Quercitannic acid	1.30†
Fiber	50.98
Ash, total	1.59
Ash, water-soluble	1.06
Ash, acid-insoluble	0.17

* By direct inversion.

† Equivalent to 0.33 per cent of O absorbed by aqueous extract.

[1] Maine Agr. Exp. Sta. 1899, Bul. **54.**

[2] U. S. Dept. Agr. 1908, Farm. Bul. **332.**

[3] Pharm. Ztg. 1909, **54,** 58.

[4] Connecticut Agr. Exp. Sta. Rep. 1898, p. 210.

Proteins.—The globulin and principal protein of the Brazil nut, later named *excelsin* by Osborne, was first crystallized from an extract of the nut by Maschke.[1] Schmiedeberg,[2] by heating a solution with magnesia and slowly evaporating, obtained crystals which he considered to be the magnesium salt of the protein, a view long accepted until Osborne [3] prepared much more perfect crystals by simply dialyzing the faintly acid saline solution in running water. These crystals were unquestionably salts of the globulin with the acid of the extract.

Osborne's crystalline preparations agreed in composition with the globulin obtained earlier by Sachsse,[4] Ritthausen,[5] and Weyl,[6] the last named being a pioneer in the extraction of globulins by means of salt solution.

The *Ultimate Composition of Excelsin*, as reported by the authors named, follows:

	Sachsse	Ritthausen	Weyl	Osborne
	%	%	%	%
Carbon	51.42	52.29	52.43	52.24
Hydrogen	7.31	7.24	7.12	6.95
Nitrogen	18.21	18.09	18.10	18.26
Sulphur	1.37	1.32	0.55	1.08
Oxygen	21.69	21.06	21.80	21.47
	100.00	100.00	100.00	100.00

Amino Acids of Excelsin.—By hydrolysis Osborne and Clapp [7] obtained the results shown on the following page, the striking feature being the high content of arginine.

Jones, Gersdorff, and Moeller [8] give the following figures for cystine and tryptophane respectively: 1.84 and 2.59 per cent.

Nitrogen Distribution in Groups.—The following figures are by Osborne and Harris: [9] basic (diamino) nitrogen 5.76, non-basic (mono-amino) nitrogen 10.97, nitrogen in magnesium oxide precipitate (humin) 0.17, and ammonia nitrogen 1.48; total 18.30 per cent.

[1] J. prakt. Chem. 1858, **74**, 436; Bot. Z. 1859, **17**, 409, 417, 429, 437.
[2] Z. physiol. Chem. 1877, **1**, 205.
[3] Am. Chem. J. 1892, **14**, 662.
[4] Sitzb. natur. Ges. Leipzig, 1876, **3**, 23.
[5] Pflüger's Archiv 1878, **16**, 301.
[6] Z. physiol. Chem. 1877, **1**, 72.
[7] Am. J. Physiol. 1907, **19**, 53.
[8] J. Biol. Chem. 1924, **62**, 183.
[9] J. Am. Chem. Soc. 1903, **25**, 323.

	%
Glycocoll	0.60
Alanine	2.33
Valine	1.51
Leucine	8.70
Serine	0.00
Cystine	0.00
Aspartic acid	3.85
Glutamic acid	12.94
Tyrosine	3.03
Phenylalanine	3.55
Proline	3.65
Oxyproline	0.00
Tryptophane	present
Arginine	16.02
Lysine	1.64
Histidine	1.47
Ammonia	1.80
	61.09

Oil.—Although the kernel of the Brazil nut is firm, resembling the cocoanut flesh in physical characters, the oil is liquid, solidifying at about the freezing point of water. It is expressed in small quantities in the countries of origin and is used for cooking and lighting. The cake must have high feeding value but no analyses are available.

Physical and Chemical Values.—The oil resembles cottonseed and sesame oils in its characteristics. The following range of values is based on results by De Negri and Fabris,[1] Grimme.[2] Merrill,[3] and Lewkowitsch:[4]

	Sp. gr. 15.5° C.	Refractive index 25° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer
						° C.
Min.	0.918	1.4643	50	193	90	31
Max.	0.921	1.4681	52	202	107	33

Schuette, Thomas, and Duthey[5] determined the values of oil expressed in a manual press without refining and of the residual oil extracted by low-boiling point petroleum ether with results as follows:

[1] Chem. Ztg. 1898, **28**, 961.
[2] Chem. Rev. Fett-Harz-Ind. 1910, **17**, 265.
[3] Maine Agr. Exp. Sta. 1900, Bul. **65**.
[4] Chem. Tech. Anal. Oils, etc. London, 1914, **2**, 235.
[5] J. Am. Chem. Soc. 1930, **52**, 4114.

VALUES OF BRAZIL NUT OIL (SCHUETTE ET AL.)

	Expressed oil	Residual oil
Sp. gr. 25°/25°	0.9150	0.9143
Refractive index at 20° C.	1.4678	1.4683
Saponification No.	194.0	198.0
Iodine No. (Wijs.)	99.92	95.21
Reichert-Meissl No.	0.0	0.31
Polenske No.	0.0	0.32
Acetyl No.	12.3	12.3
Ester No.	193.9	193.8
Free fatty acids (as oleic)	0.006%	0.02%
Fatty acids, titer	.....	33.3° C.
Soluble acids (as butyric)	0.87%	0.56%
Insoluble acids	94.16%	93.88%
Unsaturated acids (corrected)	73.0%	70.10%
Iodine No.	129.18	127.92
Saponification No.	199.6	201.2
Saturated acids (corrected)	20.29%	21.36%
Unsaponifiable matter	0.64%	0.68%

Composition.—In addition to separating the saturated and unsaturated fatty acids by the lead salt-ether method, Schuette, Thomas, and Duthey, operating with the residual oil, and Schuette and Enz,[1] operating with the expressed oil, estimated the percentages of the individual saturated acids by the methyl ester method and of the individual unsaturated acids by the bromine addition method as shown in the table below:

	Expressed	Residual
	%	%
Myristin	0.48	1.79
Palmitin	13.74	13.55
Stearin	5.45	2.58
Olein	42.79	55.64
Linolein	26.54	21.65
Unsaponifiable matter	11.00	0.68
Residues and undetermined		4.11
	100.00	100.00

[1] Ibid. 1931, **53**, 2756.

PARADISE NUT

Lecythis zabucayo Aubl.

Fr. Noix de sapucaia. It. Noce del paradiso. Ger. Sapucaja-Nuss.

This nut, also called sapucaia nut, is considered superior to the Brazil nut, which it resembles. The tree is a native of Brazil.

MACROSCOPIC STRUCTURE (Fig. 225, III).—Compared with the Brazil nut, the *nut* (4 to 8 cm.) is lighter brown, more elongated, and less conspicuously triangular, and is further characterized by marked longitudinal wrinkles. The raphe extends upward through a ridge to the chalaza at the apex, then splits into two branches which in turn divide and subdivide. As the tissues about these are disorganized, a cross section of the nut shows a ring of cavities.

MICROSCOPIC STRUCTURE. Spermoderm.—The *palisade cells* are shorter (200 to 300 μ), have relatively thinner walls (15 μ), and broader lumen (30 μ) than those of the Brazil nut, and there is no marked enlargement of the lumen at the outer end. In color the walls are light brown, whereas in the Brazil nut they are colorless.

The *brown cells* are dull brown, not red-brown as in the Brazil nut. Star-shaped cells with long arms and large intercellular spaces are conspicuous. As stated by Young,[1] large crystal rosettes occur in the inner layers.

Groups of well-marked stone cells are lacking.

Endosperm and Radicle.—Young observed that only one cell layer is present in the endosperm but that the *cortex* of the radicle is thicker and has more cell layers than that of the Brazil nut. The *aleurone grains* often exceed 20 μ but seldom reach 30 μ.

Chief Structural Characters.—Nut light brown, elongated, irregular in shape, longitudinally wrinkled.

Palisade cells shorter but with broader lumen than in Brazil nut and without enlargement at the outer end; brown cells dull brown, often star-shaped with crystal rosettes in the inner layers. Endosperm with only one cell layer. Radicle with thicker cortex but smaller aleurone grains than in Brazil nut.

CHEMICAL COMPOSITION.—The nut has practically the same composition as the Brazil nut as shown by the following analysis of the kernel given by Jaffa in his bulletin on Nuts and Their Uses:[2]

[1] U. S. Dept. Agr., Bur. Chem. 1912, Bul. **160**, 30.
[2] U. S. Dept. Agr. 1908, Farm. Bul. **332.**

Composition of Kernel of Paradise Nut (Jaffa)

Shell *	Water	Protein	Fat	N-f. ext.	Ash
%	%	%	%	%	%
45.7	2.3	22.2	62.6	10.2	2.7

* In whole nut.

Oil. *Physical and Chemical Values.*—The only available data on the characteristics of the oil are those by De Negri [1] as follows: specific gravity at 15° C. 0.895, refractive index at 25° C. (recalculated) 1.4631 to 1.4633, solidifying point 4° C., saponification number 173.6, iodine number 71.6, acetyl number 44.1, acid as oleic 3.19, solidifying point of fatty acids 28.5° C., and iodine number of fatty acids 72.3.

[1] Chem. Ztg. 1898, **22**, 961.

WEED SEEDS OF THE PARSLEY FAMILY

(Umbelliferæ)

Wild carrot seed is the only representative described in this volume. It is analogous in structure to the umbelliferous seeds used as spices and those of the garden vegetables grown for their roots.

WILD CARROT SEED

Daucus Carota L.

Fr. Carotte. Ger. Wilde Möhre.

The wild form of the carrot is a troublesome weed bearing umbels of white flowers, each with a single red-brown flower in the center. Characters of the family are described under Seeds of the Parsley Family (Volume III).

MACROSCOPIC STRUCTURE (Fig. 237).—Each of the two *mericarps* has five main ribs, the three on the dorsal side with short hairs,

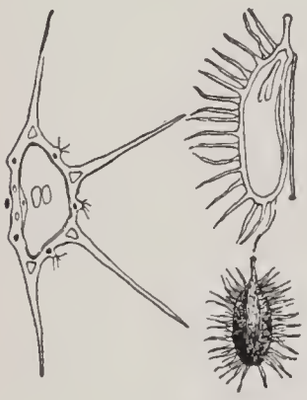


Fig. 237.

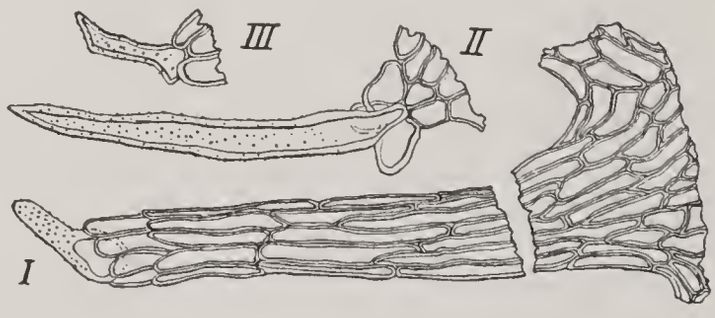


Fig. 238.

Fig. 237.—Wild Carrot. Mericarp. Left: cross section. ×8. Right: above, longitudinal section, ×4; below, dorsal view, ×2. (A.L.W.)

Fig. 238.—Wild Carrot. I bristle (emergence with terminal hair) from a secondary rib of fruit. II and III warty hairs from a primary dorsal rib. ×160. (A.L.W.)

and four secondary ribs with long bristles. Bundles occur beneath each of the five main ribs; oil ducts occur beneath each of the four secondary ribs and two on the commissural side, total of six.

MICROSCOPIC STRUCTURE.—Harz,[1] Kondo,[2] and others interested in seeds for planting have studied the microscopic structure.

Bristles (emergences) and hairs are the conspicuous elements. The *bristles* (Fig. 238, I) consist of bundles of elongated cells ending in a short, thick-walled, terminal hair, often 3 mm. long. The *hairs* (Fig. 238, II, III) are unicellular, pointed, thick-walled, and warty, reaching 300 μ in length.

In cross section the four *oil ducts* beneath the secondary ribs are triangular, the two on the commissural side elliptical.

Chief Structural Characters.—Fruit with hairs on main ribs and bristles (3 mm.) on secondary ribs. Oil ducts six.

CHEMICAL COMPOSITION.—No proximate analysis of the fruit is available but the composition is doubtless analogous to that of other umbelliferous fruits, both non-volatile (fixed) and volatile (essential) oils being present in considerable amount.

Fixed Oil.—Seed extracted with petroleum ether yields a non-drying fatty oil with a bitter taste, due, according to Reeb,[3] to *daucusin*, a glucoside which he isolated as a yellow, non-hygroscopic powder soluble in 95 per cent alcohol.

Volatile Oil. *Physical and Chemical Values.*—According to Richter,[4] the volatile oil has a characteristic odor, bitter taste, and the following values: specific gravity at 15° C. 0.9439, specific rotation at 15° C. −13.38°, saponification number 20.26, ester number 18.22, and acid number 204 (isobutyric and palmitic acids, 0.84 per cent). Quite different values were found by Asahina and Tsukamoto,[5] namely: specific gravity at 22° C. 0.9088, specific rotation at 20° C. −5.98°, saponification number 74.08, and acid number 0.

Constituents.—According to Richter,[4] the oil contains large amounts of sesquiterpenes, 7 to 9 per cent of esters, 14 per cent of *d*-pinene and *l*-limonene, an aldehyde, and *daucol* ($C_{15}H_{26}O_2$) obtained as lustrous needles melting at 115 to 116° C.

Asahina and Tsukamoto [5] were unable to isolate daucol but found a sesquiterpene, *carotol* ($C_{15}H_{26}O$), and, by the oxidation of the higher fractions, a crystalline substance ($C_{15}H_{28}O_3$) of which daucol is the anhydride.

[1] Samenkunde. Berlin, 1885, p. 1053.
[2] B. Ohara Inst. landw. Forsch. 1919, **1**, 410.
[3] J. pharm. Alsace–Lorraine 1923, **50**, 13.
[4] Arch. Pharm. 1909, **247**, 391.
[5] J. Pharm. Soc. Japan 1925, **525**, 961.

FRUIT OF THE OLIVE FAMILY

(Oleraceæ)

This family with numerous ornamental shrubs, such as the lilac, jasmine, forsythia, and privet, also species of ash valuable for timber, includes only one species of considerable importance as a food—the olive.

OLIVE

Olea europæa L.

Fr. Olive. Sp. Olivo. It. Uliva. Ger. Olive.

Of the few economic fruits that have an oily fruit flesh, the olive is unmistakably the most valuable. Others described in this treatise are the oil palm, the Chinese olive, and the avocado.

In the eastern Mediterranean region where it is native the olive tree has been cultivated since prehistoric times. For centuries olives and olive oil have been among the most important products of Italy, southern France, Spain, Greece, and northern Africa. California, Mexico, Chile, and Peru now produce olives in large quantities.

The olive is remarkable for its longevity, the skeletonized trunks of still living trees forming picturesque objects in subtropical landscapes.

Olive pomace has value as a cattle food, but the stones have no legitimate use in food, the addition of ground olive stones to white pepper being a fraud which European food analysts are continually combating. Both green (immature) and ripe olives are salted, the process in the latter case involving treatment with lye to remove the bitter principles.

MACROSCOPIC STRUCTURE.—Olives vary, according to variety, from oval to nearly round and in color from green or white, through shades of blue, purple, and red to black. The *fruit* is a drupe, the hard elongated stone consisting of endocarp and a single seed, one of the two ovules of the two-celled ovary being abortive. The *seed* is anatropous, suspended in the fruit cavity. It has a thin spermoderm and an elongated embryo embedded, with radicle directed upward, in the endosperm. The cotyledons are narrow, several times the length of the radicle.

MICROSCOPIC STRUCTURE.—Because of the adulteration of pepper with olive stones, several authors have described the structure

of the endocarp and seed and various staining tests have been devised to distinguish the stone cells from those normally present in pepper. These tests seem superfluous to one familiar with the tissues.

The writers in this and previous works have not overlooked the part of the fruit where the real food matter is located.

Pericarp.—A cross section (Fig. 239) through the flesh (outer pericarp) of a firm but mature fresh olive shows three tissues: (1) *epicarp* (Fig. 239, *epi*; Fig. 240) of cells about 25 μ in diameter with greatly thickened outer and radial walls; (2) *hypoderm* (*hy*) of several layers of flattened cells with moderately thick walls, and (3) *mesocarp* of thin-walled oil parenchyma (*ol*), the cells ranging from isodiametric in the outer portion to radially elongated in the inner portion, interspersed with grotesque, thick-walled stone cells (*st*).

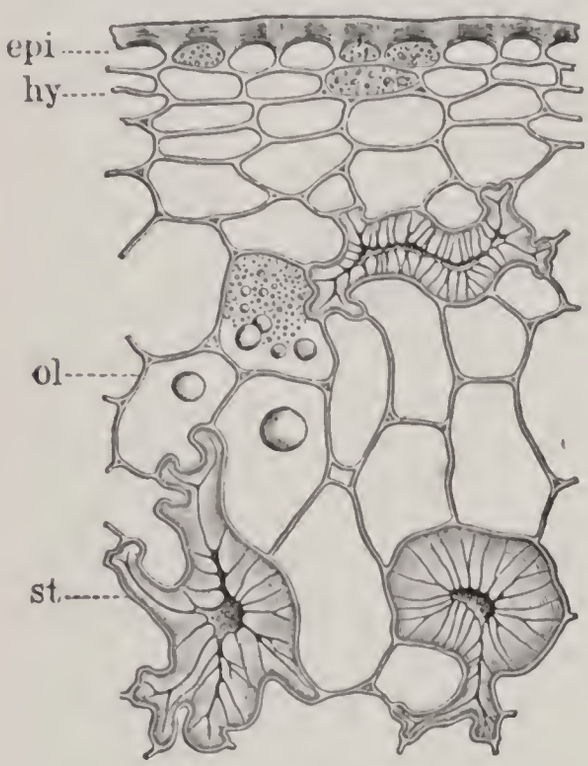


Fig. 239.

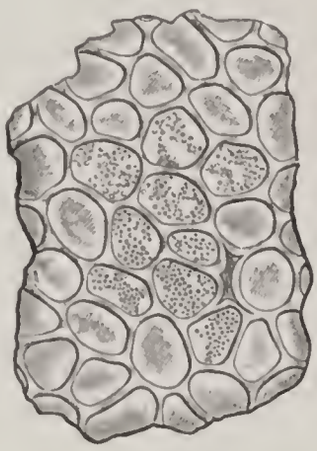


Fig. 240.

Fig. 239.—Olive. Outer pericarp in cross section. *epi* epicarp; *hy* hypoderm; *ol* oil parenchyma; *st* stone cells. ×160. (K.B.W.)

Fig. 240.—Olive. Epicarp in surface view. ×160. (K.B.W.)

Oil occurs throughout the outer pericarp or fruit flesh, being especially noticeable in the larger cells where it forms large and small drops. Mounted in a fat solvent, such as kerosene oil, minute granules remain which deserve further study.

The *stone cells*, occurring singly or in small groups, are remarkable for the endless variety of curious forms with branching outgrowths. They apparently vary considerably in number in different varieties. Like the adjoining thin-walled cells they show a tendency to radial elongation.

The *endocarp* (Fig. 241, *F*) consists of three layers: (1) outer stone cells (st^1), which are large, isodiametric or transversely elongated, often with a large lumen, (2) inner stone cells (st^2), which are narrow and

transversely elongated, and (3) parenchyma (p^1) more or less compressed.

The *stone cells* are remarkably colorless as are also the contents if present.

Spermoderm (Fig. 241, *S*; Fig. 242).—Cross sections show: (1) *outer epiderm* (*aep* [1]) of large cells, often tangentially elongated, with greatly swollen outer and radial walls, (2) *parenchyma* (p^2), the cells varying from polygonal to circular and containing small crystals, and (3) *inner epiderm* which together with the adjoining parenchyma is more or less compressed.

In surface view the *outer epiderm* is remarkable for the size of the cells and the swollen, often porous walls.

Endosperm (Fig. 241, *E*; Fig. 242).—

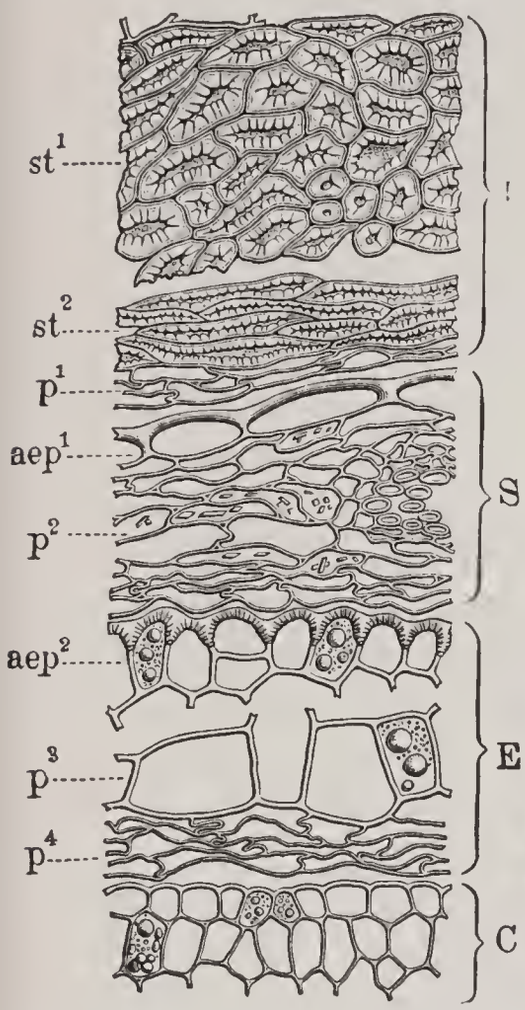


Fig. 241.—Olive. Stone in cross section. *F* endocarp: st^1, st^2 stone cells, p^1 parenchyma. *S* spermoderm: aep^1 outer epiderm, p^2 parenchyma with crystals and vascular bundle. *E* endosperm: aep^2 outer epiderm, p^3 oil parenchyma, p^4 collapsed parenchyma. *C* cotyledon. ×160. (K.B.W.)

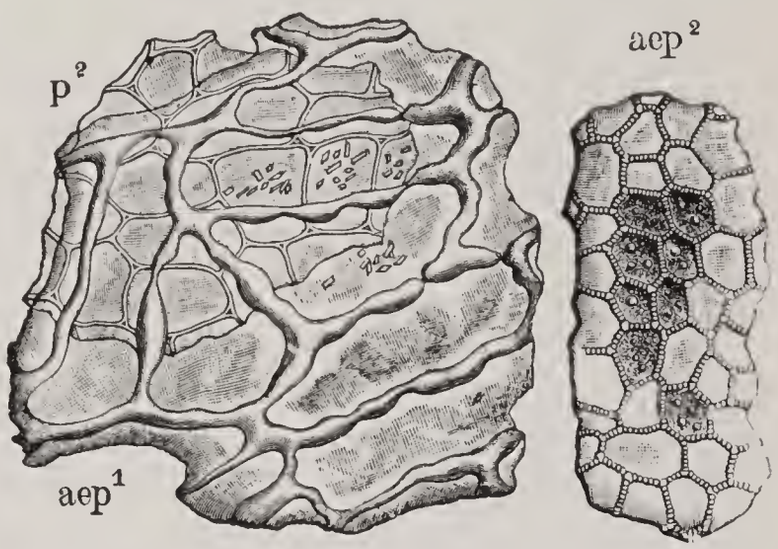


Fig. 242.—Olive. Seed elements in surface view. Spermoderm: aep^1 outer epiderm, p^2 parenchyma. Endosperm: aep^2 outer epiderm. ×160. (K.B.W.)

Seen in cross section there are at least three distinct tissue zones: (1) *outer epiderm* (aep^2) of porous cells with thick outer walls, (2) *parenchyma* (p^3) of large cells with straight walls of medium thickness, and (3) compressed thin-walled *parenchyma* (p^4).

In addition to oil drops the parenchyma contains aleurone grains up to 20 μ.

The **Cotyledons** (Fig. 241, *C*) are made up of small cells containing oil and small aleurone grains (10 μ).

Chief Structural Characters.—Fruit oval or round, variously

colored. Outer pericarp oily; inner pericarp hard. Spermoderm thin, endosperm with embryo in axis.

Outer pericarp with oil cells and grotesque stone cells; endocarp of large isodiametric or elongated stone cells and narrow, tangentially much elongated stone cells. Spermoderm of large outer epidermal cells with swollen walls and parenchyma containing crystals. Endosperm containing oil and aleurone grains (20 μ); outer epiderm porous. Cotyledon cells small, containing oil and small aleurone grains (10 μ).

CHEMICAL COMPOSITION.—Colby [1] states that during the eight years ending January 1, 1899, over 740 samples of olives were examined at the California Station with respect to size, ratio of pit to flesh, and oil content of flesh and pit. The olives appear to have been gathered when ripe, at a time suited for oil manufacture or pickling. Nine of the varieties examined were classed as "fully tested" and 48 as "not fully tested." The average analysis of each of the 9 fully tested varieties and of 8 of the others, selected to represent the extreme results, appears in the table on the following page.

This table does not show the full range in size or composition. Of the 420 samples examined up to 1897 [2] the number of olives in 100 grams ranged from 11 to 132, the available flesh from 60 to 90 per cent, the oil in the whole fruit from 5 to 35 per cent (to 29 in the leading varieties), and the oil in the flesh from 7 to 47 per cent (to 36 in the leading varieties).

Hilts and Hollingshead [3] consider that the percentage of oil in the fruit flesh is the best index of maturity. If a minimum of 17 per cent for Mission olives and 15 per cent for Manzanillo olives is adopted, the temptation to color green fruit in imitation of ripe will be removed. Large-fruited olives, such as Ascolano and Sevillano, must, however, be gathered when more immature.

Pickled Olives.—Although the bitterness of the fruit may be removed by long preliminary soaking with frequent change of water and the product thus obtained is of superior quality, treatment with 1.6 to 2.0 per cent lye is the only method practiced on a commercial scale. The alkaline solution and the subsequent washing remove, in addition to bitter principles, proteins and certain other organic and inorganic constituents. The brine added after removal of the lye is also a protein solvent. Cruess [4] recommends for Manzanillo, Mission, and Barouni varieties 11 per cent brine, reduced to 7.5 per cent after fermentation,

[1] California Agr. Exp. Sta. 1899, Bul. **123**.
[2] California Agr. Exp. Sta. Rep. 1895/7, p. 193.
[3] U. S. Dept. Agr., Bur. Chem. 1920, Bul. **803**.
[4] California Agr. Exp. Sta. 1930, Bul. **498**.

Averages by Varieties of Fresh Ripe California Olives (Colby)

Variety	Samples	Olives per 100 grams	Pit	Oil in whole fruit	Oil in flesh	Oil in pit *
			%	%	%	%
Fully tested:						
Mission	112	50.7	17.2	17.56	22.51	0.61
Nevadillo Blanco	57	71.4	17.3	19.21	22.92	0.99
Manzanillo	38	48.4	14.7	16.94	19.73	0.55
Redding Picholine	42	180.8	23.0	16.18	20.83	1.52
Uvaria	29	93.1	25.5	13.71	18.51	1.07
Rubra	35	89.0	17.9	18.58	22.01	0.75
Oblonga	32	81.4	18.7	13.34	15.68	0.85
Columbella	25	52.0	16.6	15.59	19.54	0.60
Pendulina	22	71.0	13.7	18.63	21.36	0.96
Not fully tested:						
Morchiaio	4	108.1	23.0	29.34	37.99	0.36
Moraiolo	3	151.3	33.0	21.74	32.22	1.45
Mignolo	1	103.1	12.0	16.50	18.70	
Ascolano	5	27.5	12.0	16.26	18.45	0.57
Obliza	5	47.8	14.6	11.23	13.42	0.37
Huff's Spanish	2	193.3	25.0	16.50	21.99	0.99
"Queen"	2	63.6	24.0	27.67	36.30	
Sevillano	2	16.4	14.5	17.23	20.19	0.40

* Per cent of whole fruit.

and for Sevillano and Ascelano varieties 5 per cent brine, gradually raised to 7 to 8 per cent. Small quantities of acetic or lactic acid and glucose hasten the fermentation.

Sterilization of pickled olives at 240° F. (114° C.) has become necessary in order to destroy the deadly *Bacillus botulinus*. To avoid the development of a bitter or scorched flavor Cruess [1] recommends thorough treatment with lye of at least 1 per cent strength, complete removal of the lye, soaking in 8 to 9 per cent brine 4 to 6 days, and canning in 2 to 2.5 per cent brine.

Pickled ripe olives are preferred by nutritionists and epicures. Bioletti,[2] who describes the different processes, states that they "constitute an extremely nutritious and digestible form of food. They contain a large amount of oil, carbohydrates and some nitrogenous matter, and in some countries replace meat to a certain extent. Pickled green olives such as those imported from Spain are on the contrary indi-

[1] Ibid. Rep. 1920, p. 48; 1921, Bul. **333.**

[2] California Agr. Exp. Sta. 1899, Bul. **123,** 1.

gestible and contain much less nutrient. They are made from unripe fruit and are therefore, as far as their use for food is concerned, in no way superior to unripe apples or peaches."

The following table, prepared by Jaffa, is given by Bioletti to illustrate the superiority of the ripe pickles:

Composition of Edible Part of Pickled Olives (Jaffa)

	Water	Oil	Carbohydrates	Other matter
	%	%	%	%
Ripe, from California:				
Medium-sized Mission I	64.72	25.89	4.28	5.11
Medium-sized Mission II	65.45	25.15	3.22	6.18
Larger, watery Mission	72.77	18.81	2.49	5.93
Green, "Queen" from Spain	78.41	12.90	1.78	6.91

The proximate composition of the edible part of 4 samples of ripe and 1 of green olives has been determined by Stathopoulos [1] and of 1 sample each of green and ripe olives has been reported by Atwater and Bryant.[2] In the former case it was necessary to calculate the percentages of protein and nitrogen-free extract from the data given in the paper.

Composition of Edible Part of Pickled Olives

	Shell *	Kernel *	Flesh *	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Salt	P_2O_5
	%	%	%	%	%	%	%	%	%	%	%
Stathopoulos:											
Green	6.2	16.3	77.5	67.96	1.56	15.26	3.97	1.05	10.20	9.92	0.04
Ripe											
Min.	5.3	20.0	67.8	34.50	1.44	23.31	12.41	2.99	3.14	0.20	0.002
Max.	9.1	24.3	70.8	51.81	3.94	30.99	20.51	5.42	10.14	10.08	0.08
A. and B.:											
Green	27.0		73.0	58.0	1.1	27.6	11.6		1.7	....	....
Ripe	19.0		81.0	64.7	1.7	25.9	4.3		3.4	....	....

* In whole fruit.

Oil.—As noted above, the oil is chiefly in the fruit flesh (mesocarp) from which is expressed the oil of commerce. Being the most esteemed and highest priced of the salad oils, its purity has been carefully guarded by production and control analysts. The great bulk of the analyses,

[1] Chem. Umschau 1925, **32**, 73.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. 28 rev.

however, have been made on oils of uncertain origin and purity and hence are of only temporary value.

The small amount of oil in the kernel of the pit resembles that of the flesh but when prepared from the pomace the oil is often of a low grade unsuited for food.

Physical and Chemical Values are invaluable when the question of purity is involved and also serve a still more important purpose as indexes of grade and uniformity.

The following summaries of values by Müntz, Durand, and Milliau,[1] Colby,[2] De Negri and Frabris [3] and Tolman and Munson,[4] are from Tolman and Munson's bulletin:

VALUES OF AUTHENTIC OLIVE OIL (MÜNTZ, DURAND, AND MILLIAU)

	Samples	Sp. gr. 15.5° C.	Maumené No.	Iodine No. (Hübl)	Fatty acids, m. pt.	Fatty acids, titer
					° C.	° C.
France:	7					
Min.....	.....	0.9154	30.0	83.5	24.0	22.5
Max.....	.....	0.9168	35.0	84.1	25.0	24.0
Spain:	..					
Min.....	.....	0.9160	30.0	83.8	24.0	22.0
Max.....	.....	0.9160	35.0	83.8	24.0	22.0
Portugal:	..					
Min.....	.....	0.9167	30.0	84.1	24.5	23.5
Max.....	.....	0.9167	35.0	84.1	24.5	23.5
Greece:	..					
Min.....	.....	0.9160	30.0	84.3	25.0	23.5
Max.....	.....	0.9160	35.0	84.3	25.0	23.5
Turkey:	..					
Min.....	.....	0.9162	30.0	84.1	24.5	23.0
Max.....	.....	0.9162	35.0	84.1	24.5	23.0
Levant:	..					
Min.....	.....	0.9165	30.0	83.5	24.5	23.0
Max.....	.....	0.9165	35.0	83.5	24.5	23.0
Africa:	4					
Min.....	.....	0.9169	30.0	84.1	24.0	22.5
Max.....	.....	0.9172	35.0	84.5	26.0	24.5
Tunis:	15					
Min.....	.....	0.9150	.....	81.4	24.0	22.5
Max.....	.....	0.9182	.....	85.2	27.0	25.0

[1] Bul. Ministère Agr. 1895, 139.

[2] California Agr. Exp. Sta. Rep. 1897–98, p. 165.

[3] Ann. Lab. chim. centr. Gabelle, **2**, Gli Olii II, 114.

[4] U. S. Dept. Agr., Bur. Chem. 1903, Bul. **77.**

The following is the range of values of California olive oil as given by Colby: specific gravity at 15.5° C. 0.9140 to 0.9185, refractive index at 15.5° C. 1.4689 to 1.4717, saponification number 187.0 to 193.5, iodine number (Hübl) 77.7 to 93.5, and melting point of fatty acids 21.0 to 26.0° C.

It should be noted that the iodine number of the California product, as determined by Colby, is well above the limit usually placed for genuine olive oil. It appears, however, that the oil of that state is not the only exception to the rule, for Thomson and Dunlop [1] obtained an iodine number of 93.67 in oil from the Punjab, and Archbutt [2] found as high as 94.7 in Tunisian oil and over 90 in several samples of Algerian oil.[3]

Tolman and Munson (see table below) obtained their samples of Italian olive oils through Dr. V. Villavecchia, of the Custom House, Rome, a recognized authority on olive oils, and from Giacomo Dellapaine fu Andrea, of Genoa. Some of their samples of California oils were from the California Experiment Station, and some (accompanied by affidavits) from reputable producers.

VALUES OF AUTHENTIC OLIVE OIL (TOLMAN AND MUNSON)

	Samples	Sp. gr. 15.5° C.	Refractive index 15.5° C.	Maumené No.	Saponification No.	Iodine No. (Hübl)	Fatty acids, m. pt.	Fatty acids, solid	Fatty acids, liquid	Fatty acids, free
							° C.	%	I No.	%
Italy:	18									
Min.		0.9155	1.4705	39.6	189.6	79.2	21.6	5.01	89.8	0.57
Max.		0.9180	1.4713	49.1	192.0	86.1	29.3	17.72	98.4	2.79
Aver.		**0.9163**	**1.4709**	**44.9**	**190.9**	**81.6**	**25.5**	**10.50**	**94.0**	**1.11**
California:	39									
Min.		0.9162	1.4703	38.0	189.3	78.5	19.2	2.02	88.9	0.20
Max.		0.9180	1.4718	52.1	194.4	89.8	31.0	12.96	96.6	44.40*
Aver.		**0.9170**	**1.4713**	**46.9**	**190.9**	**85.3**	**22.9**	**5.86**	**92.8**	**1.20**

* Not included in average.

The following values were obtained by Jamieson and Baughman [4] in the California olive oil as part of the data from which they calculated its composition as given below: specific gravity, 25°/25°, 0.9119; refractive index at 20° C. 1.4690; saponification number 190; iodine number (Hanus) 85.1; acid number 1.5; acetyl number 11.2; saturated acids

[1] Analyst, 1906, **31**, 282.

[2] J. Soc. Chem. Ind. 1907, **26**, 453, 1185.

[3] See Lewkowitsch: Chem. Tech. Anal. Oils, etc. London, 1914, **2**, p. 359.

[4] J. Oil Fat Ind. 1925, **2**, 40.

VALUES OF AUTHENTIC OLIVE OIL (DE NEGRI AND FABRIS)

	Samples	Sp. gr. 15.5° C.	Maumené No.	Saponification No.	Iodine No. (Hübl)
Green fruit:	18				
Min	.....	0.9160	32.0	187.9	79.1
Max	.....	0.9180	36.5	192.2	88.3
Ripe fruit:	17				
Min	.....	0.9145	33.0	185.0	81.1
Max	.....	0.9178	36.5	192.0	89.8
Various sources:	53				
Min	.....	0.9160	32.0	188.8	79.0
Max	.....	0.9180	37.0	192.3	87.1

9.7 per cent (iodine number 7.5); unsaturated acids plus unsaponifiable matter 85.6 per cent (iodine number 95.7); unsaturated acids, iodine number 94.8; saturated acids, corrected, 8.9 per cent; and unsaturated acids, corrected, 85.2 per cent.

Täufel and Sarria[1] report the following values: specific gravity at 18.5° C. 0.914, oleorefractometer reading at 25° C. 61.9 (refractive index 1.4672), saponification number 192.6, iodine number 82.7, Reichert-Meissl number 0.13, Hehner number 95, melting point of fatty acids 28.2°, and acid number 0.62. The calculated glycerides of the fatty acids appear in the table below.

Composition of Olive Oil.—The following table contains the percentages of the different glycerides as obtained by Jamieson and Baughman [2] in California olive oil, as obtained by Baughman and Jamieson [3] in Italian olive oil of the Bitonto type, and as calculated by the writers from the percentages of the fatty acids given by Täufel and Sarria[1] in Spanish olive oil. Täufel and Sarria found in the Spanish oil triolein and α-palmitodiolein but no arachidic acid.

Qualitative Reactions.—A lack of characteristic color tests for olive oil is not so great a misfortune as would be the lack of such tests as Halphen's and Bechi's for cottonseed oil, Baudouin's for sesame oil, and Renard's for peanut oil, which are invaluable in detecting these cheaper oils in commercial olive oil. It must not, however, be forgotten that on the one hand skilful treatment of these oils, such as heating cottonseed oil, may render them inert to the tests and on the other hand

[1] An. soc. españ. fis. quim. 1926, **24**, 25.
[2] Loc. cit.
[3] J. Oil & Fat Ind. 1925, **2**, 110.

Composition of Olive Oil

	California	Italian	Spanish
	Jamieson and Baughman	Baughman and Jamieson	Täufel and Sarria
	%	%	%
Glycerides of:			
Arachidic acid	0.1	0.2	none
Stearic acid	2.3	2.0	2.37
Palmitic acid	6.9	9.2	7.90
Myristic acid	trace	trace	
Oleic acid	84.4	83.1	87.72
Linolic acid	4.6	3.9	0.53
Unsaponifiable matter	1.0	1.1	0.79
	99.3	99.5	99.31

genuine olive oil from certain regions may occasionally give misleading color reactions. For example, Tunisian olive oil at times responds to the Baudouin test and pure olive oil from various regions may reduce silver to a slight extent when submitted to the Bechi test. In applying Renard's test, allowance must be made for the small amount of arachidic acid now known to be present sometimes, if not always, in olive oil.

Oleonol.—Unlike oil seeds the unripe olive, as examined by Scurti and Tommasi,[1] does not appear to contain a considerable amount of carbohydrate which passes into reserve fat. The fat is more probably a waste product. The immature mesocarp contains a waxy alcohol, oleonol ($C_{31}H_{50}O_3$), previously discovered by Canzoneri[2] in the leaves. It is believed that on ripening this passes into fatty acids and the latter in turn pass completely into neutral fat.

Glucosides.—*Oleuropein*, a bitter glucoside discovered by Bourquelot and Vintilesco,[3] is an amorphous, yellow powder, soluble in cold water. The solution is colored yellow by alkali, red by concentrated sulphuric acid, and green by ferric chloride. It is partially precipitated from an aqueous solution by lead subacetate, reduces copper solution, and is optically active ($\alpha_D = -127°$). On hydrolysis it yields *d*-glucose and a brownish precipitate. It has an intensely bitter taste. During July it begins to diminish and during October it disappears completely.

[1] Ann. staz. chim. agr. sper. Roma, 1910, 2 ser. **4**, 253.

[2] Gaz. chim. ital. 1906, **36**, II, 372.

[3] Compt. rend. 1908, **147**, 533; J. pharm. chim. **28**, 303.

Bioletti[1] found that oleuropein is not destroyed by neutralization with alkali or by a slight excess but an excess of 2 per cent of potassium hydroxide immediately removes the bitter taste and 0.7 per cent removes it in 24 hours. When heated under pressure a small excess of alkali suffices.

Enzymes.—Olives contain a *lipase* which Tolomei[2] calls "olease." It is considered necessary to press the pulp promptly in order to restrain the acid-forming action of the enzyme. Rector[3] found that filtered olive oil prepared without chemicals still contained an appreciable amount of the enzyme, which is partially destroyed on heating 15 minutes at 75° and completely at 150° C., but that the foots contain an anti-enzyme.

Mineral Constituents.—The following analysis of the ash of the olive fruit was made at the California Agricultural Experiment Station:[4]

Analysis of Olive Fruit Ash

Ash*	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
1.42	60.74	2.23	16.28	3.77	0.10	8.33	1.10	5.67	1.58

* In fruit.

Minor Mineral Constituents. *Manganese.*—Pulp 1.66, stone 2.5 mg. per kilo, dry basis (Quartaroli).[5]

Copper.—Fruit, fresh basis 2.8, dry basis 8.3 mg. per kilo (Guerithault).[6] Pulp 1.8, stone 6.25 mg. per kilo, dry basis (Quartaroli).[5]

[1] California Agr. Exp. Sta. 1914, p. 197.
[2] Atti accad. Lincei 1896.
[3] J. Ind. Eng. Chem. 1920, **12**, 156.
[4] Rep. 1890, p. 150; Abs. Exp. Sta. Rec. 1892, **3**, 593.
[5] Ann. chim. appl. 1928, **18**, 47.
[6] Compt. rend. 1920, **171**, 196.

SEEDS OF THE PEDALIUM FAMILY

(*Pedaliaceæ*)

SESAME seed is the important oil seed of the family.

SESAME SEED

Sesamum indicum (L.) D.C. = *S. indicum* L. + *S. orientale* L.

Fr. Sésame. Sp. Sésamo. It. Sesamo. Ger. Sesam.

Linnæus gave to the races that produce light-colored seeds the specific name *S. indicum*, to those producing dark seeds the name *S. orientale*, but De Candolle considered that both belong to the same species. As a result of different grouping, the genus *Sesamum* has been tossed from one family to another—*Bignoniaceæ*, *Sesamaceæ*, *Martyniaceæ*, *Gesneraceæ*, and *Pedaliaceæ*, the last named being at present most generally accepted.

The plant is commonly believed to be a native of India, but De Candolle, though admitting its cultivation there for two or three thousand years, inclines to the view that it originated in the Sunda Islands. At present it is extensively grown in tropical and subtropical Asia, the Sunda Islands, Egypt, and other Mediterranean countries, also in South America and to a very limited extent in the United States.

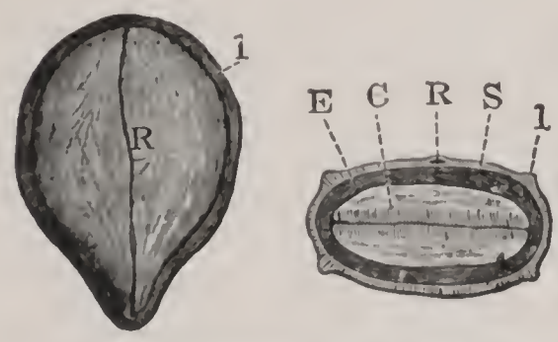


FIG. 243.—Sesame Seed. Left, outer surface; right, cross section. *S* spermoderm with *l* ridges and *R* raphe; *E* endosperm; *C* cotyledon. ×8. (A.L.W.)

It is indeed one of the world's great food plants, especially in India and other Asiatic countries, the seed being used as an ingredient of bakery products and confectionery, the oil for cooking and salads, and the cake as food for cattle and even people of the poorer classes.

MACROSCOPIC STRUCTURE.—Among the characters of the *flower* are the short five-parted calyx, the two-lipped yellow or pinkish corolla (the upper lip with two lobes, the lower with three), the four stamens, and the four-sided ovary. The *pod* is about 2 cm. long and has two locules but appears to be four-loculed owing to false partitions.

The *seed* (Fig. 243) is flattened pear-shaped, up to 3 mm. long, and varies in color from light straw to dark brown. An indistinct longitudinal ridge through the center of one of the sides marks the position of the raphe (*R*). Other ridges (*l*) run around each side near the edge. Median cross sections show the spermoderm (*S*), the endosperm (*E*), and the bulky cotyledons (*C*) the latter being two to three times as long as the radicle.

MICROSCOPIC STRUCTURE.—Harz,[1] Böhmer,[2] and later authors give due attention to this seed. Hebebrand,[3] in his monograph on sesame, gives a plate showing the histological structure of the seed as well as the gross characters of the plant and the lens structure of the pod and seed.

Spermoderm (Fig. 244, *S*; Fig. 245).—Only one cell layer, the *outer epiderm* (*ep*) is distinctly evident, even after special treatment. Beneath this is one collapsed layer of *parenchyma* (*p*) which may be partially expanded by Javelle water or heating with sodium hydroxide. In this Hanausek[4] notes the presence of crystals of calcium oxalate. A yellow membrane (*m*), apparently a cuticle, forms the inner boundary of the spermoderm.

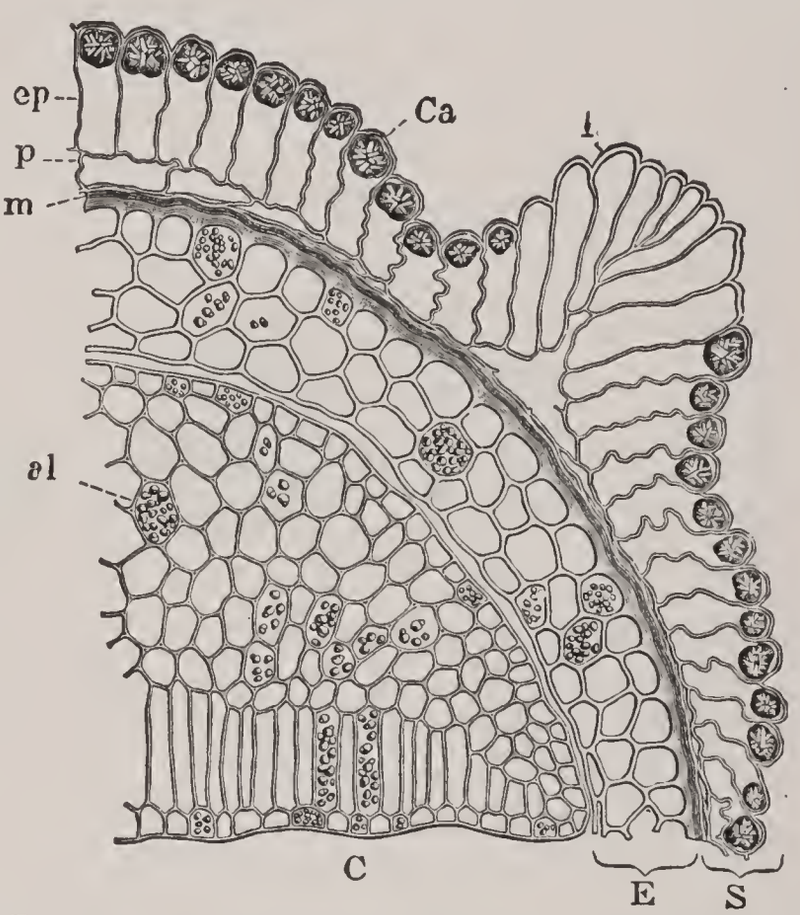


FIG. 244.—Sesame Seed. Cross section. *S* spermoderm: *ep* outer epiderm with *Ca* crystal masses, *l* epidermal cells of ridges, *p* parenchyma, *m* inner cuticle. *E* endosperm. *C* cotyledon with *al* aleurone grains. ×160. (A.L.W.)

Returning to the *outer epiderm*, both cross sections and surface preparations are necessary to study its characters. Owing to the thin radial walls, treatment with the reagents named above is advisable. The cells are radially elongated and each contains at its outer end a rounded mass consisting of oxalate crystals within a membrane or coating.

[1] Samenkunde. Berlin, 1885, p. 960.

[2] Kraftfuttermittel. Berlin, 1903, p. 503.

[3] Landw. Vers.-Stat. 1898, **51**, 45.

[4] Lehrbuch tech. Microskopie. Stuttgart, 1901, p. 379. Microscopy Technical Products. New York, 1907, p. 382.

These masses are oftentimes disintegrated, the individual crystals being evident (Fig. 245, *Ca*). In surface view the cells are isodiametric.

The cells forming the ridges do not contain crystal masses. As first noted by Benecke,[1] these cells are arranged like the barbs of a feather and have strongly thickened outer walls. In surface view they are somewhat elongated.

Endosperm (Figs. 244 and 245, *E*).—The cell layers range from two at the edges to five on the side. All the walls are thick enough to be rigid and the outer walls are further thickened. *Aleurone grains* up to 6 μ and *fat* are the visible contents.

Embryo.—Cross sections of the cotyledon (Fig. 244, *C*) show one layer of *palisade cells* adjoining the *inner epiderm*, the remainder of the ground tissue being of isodiametric cells. The aleurone grains reach 10 μ and each contains, according to Hanausek, a crystalloid or a globoid.

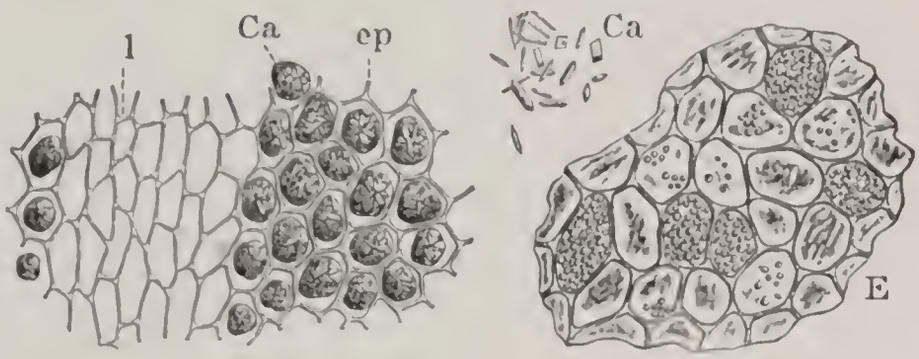


Fig. 245.—Sesame Seed. Spermoderm and endosperm in surface view. *ep* outer epiderm of spermoderm with *Ca* crystal masses; *l* epidermal cells of ridges; *E* endosperm. ×160. (A.L.W.)

Chief Structural Characters.—Seed (3 mm.) flattened, pear-shaped, yellow or brown, with ridges over raphe and about edge on both sides. Cotyledons somewhat bulkier than endosperm.

Spermoderm with outer epiderm of radially elongated palisade cells each containing a crystal mass in outer end. In African sesame (*S. radiatum*) the crystal mass is in the inner end where the wall is thickened. Endosperm and embryo containing fat and aleurone grains reaching in cotyledon 10 μ.

CHEMICAL COMPOSITION.—Hebebrand,[2] acting as reporter for the Association of German Experiment Stations, prepared a monograph on sesame, fully treating the subject in its various phases, with a bibliography of thirty-nine titles. Böhmer[3] and Collin and Perrot[4] each

[1] Pharm. Centralh. 1897, 549.
[2] Landw. Vers.-Stat. 1898, **51**, 45.
[3] Kraftfuttermittel. Berlin, 1903, p. 494.
[4] Résidus industriels. Paris, 1904, p. 263.

devotes a chapter to sesame by-products. No American analysis has come to the writers' notice.

The following summary of analyses of the seed, reported by Schaedler,[1] Hebebrand,[2] and Dietrich and König,[3] is quoted from Böhmer's Kraftfuttermittel:

Composition of Sesame Seed

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min	4.71	19.49	35.13	10.73	1.70	3.42
Max	7.06	22.69	56.75	28.76	11.19	8.47
Aver	**5.61**	**21.12**	**46.78**	**18.63**	**5.08**	**6.02**

More complete analyses are those by Hebebrand given in the following table:

Composition of Sesame Seed and Cake (Hebebrand)

	White East Indian seed	Black East Indian seed	Levantine yellow seed	Press Cake Mannheim factory
	%	%	%	%
Water	5.42	6.50	5.25	8.72
Protein, crude	22.69	21.77	19.49	41.95
Protein, crude, digestible	20.98	19.61	17.89	40.13
Protein, pure	21.68	18.36	19.03	40.08
Protein, water soluble	3.39	.....	2.79	5.52
Amides, amines	1.01	3.41	0.46	1.87
Fat	52.75	51.40	56.76	13.45
Free fatty acids as oleic	1.64	1.69	1.58	11.84
N-free extract	6.30	8.44	6.04	12.34
N-free extract, water soluble	5.08	.....	4.81	10.78
Pentosans	4.69	4.74	4.69	8.65
Fiber	2.88	1.70	3.71	5.35
Ash	5.27	5.45	4.07	9.54
Ash, water soluble	1.40	.....	1.12	1.73
Sand	0.10	0.10	0.18	0.08

Ram[4] states that rough-seeded varieties, because of the large per-

[1] Tech. Fette, etc., 1883.

[2] Loc. cit.

[3] Zusammens. Verd. Futterm. 1891.

[4] Mem. Dept. Agr. India, Bot. Ser. 1930, **18**, 127.

centage of hulls yield only 38 to 41 per cent of oil whereas smooth-seeded varieties yield 47 to 51 per cent.

Sesame Cake.—Hebebrand [1] states that 786 samples examined in German experiment stations from 1877 to 1898 contained: protein 27.70 to 48.56 and fat 3.79 to 26.82 per cent.

Proteins.—Ritthausen [2] isolated two globulins designated *legumin* and *globulin*. Jones and Gersdorff,[3] by heating to 68° C., precipitated from a 10 per cent brine extract of defatted sesame cake 1.52 per cent of a *coagulum*, also, by addition of ammonium sulphate to 20 to 30 per cent and 69 per cent saturation respectively, 24.35 per cent of crystalline *α-globulin* and 5.66 per cent of amorphous *β-globulin*.

The *Ultimate Composition* of these proteins follows:

	Legumin	Globulin	Coagulum	α-Globulin	β-Globulin
	%	%	%	%	%
Carbon	51.19	51.19	44.58	53.32	48.64
Hydrogen	7.28	7.15	7.28	6.74	6.68
Nitrogen	16.96	18.38	12.09	18.44	17.57
Sulphur	1.12	1.40	0.80	1.28	0.82
Oxygen	23.45	21.88	35.25	20.22	26.29
	100.00	100.00	100.00	100.00	100.00

Amino Acids.—The following results are by Jones and Gersdorff:

	Coagulum	α-Globulin	β-Globulin
	%	%	%
Arginine *	8.60	15.07	15.58
Histidine *	2.36	2.68	3.45
Lysine *	2.53	5.43	3.99
Cystine †	1.41	1.94	1.47
Tryptophane †	2.72	2.77	2.65
Tyrosine †	4.31	4.72	4.48

* Van Slyke method. † Colorimetric method.

Nitrogen Distribution.—Results on the coagulum, α-globulin, and β-globulin in the order named follow: amide N 4.34, 9.48, 10.62; humin

[1] Loc. cit.

[2] Pflüger's Arch. 1880, **21**, 81; J. prakt. Chem. 1881, **23**, 481; Landw. Vers.-Stat. 1896, **47**, 391.

[3] J. Biol. Chem. 1927, **75**, 213.

N absorbed by lime 3.26 (doubtless due to carbohydrates), 1.00, 1.21; humin N in ether-amyl alcohol extract 9.95, 0.10, 0.36; cystine N 3.79, 1.01, 1.05; arginine N 22.86, 26.28, 28.10; histidine N 5.28, 3.93, 5.24; lysine N 4.00, 5.64, 4.29; amino N of filtrate 21.78, 50.96, 48.63; non-amino N of filtrate 24.78, 2.26, 1.54 per cent.

Oil.—The oil is semi-drying, resembling in its characters cottonseed oil. Cold-pressed sesame oil from ground seed is an excellent salad and cooking oil. Hot-pressed oil is inferior and finds its chief use in soap-making.

Physical and Chemical Values.—The maximum and minimum limits of various observers follow:

VALUES OF SESAME OIL

	Sp. gr. 15.5° C.	Refr. index 25° C.	Maumené No.	Saponification No.	Iodine No.	Reichert-Meissl No.	Fatty acids, titer	Acid No.	Unsaponifiable matter
							° C.		%
Min...	0.920	1.4707	61	187	103	0.5	20	0.5	0.5
Max..	0.926	1.4725	72	193	115	2.0	24	3.0	2.0

The results obtained by Jamieson and Baughman [1] and used as data in calculating the composition of the oil follow: specific gravity 25°/25° C. 0.9187; refractive index at 20° C. 1.4731; saponification number 189.3; iodine number (Hanus) 110.8; Reichert–Meissl number 0.11; Polenske number 0.15; acetyl number 9.8; saturated acids, determined 12.8 per cent (iodine number 6.2); unsaturated acids and unsaponifiable matter, determined 82.3 per cent (iodine number 129.0), saturated acids, corrected 12.2 per cent; unsaturated acids, corrected 81.2 per cent (iodine number 129.7); acid number 1.4; unsaponifiable matter 1.73 per cent (iodine number 96.3).

Composition of Sesame Oil.—Lane [2] separated by the lead salt method 78.1 per cent of liquid fatty acids consisting of oleic and linolic acids. By the tetrabromide method Lewkowitsch,[3] also Farnsteiner and Lane whom he quotes, isolated about 15 per cent of linolic acid, but Lewkowitsch notes the lack of correspondence of the amounts found with the iodine number. Jamieson and Baughman,[1] as shown in the table below, found over twice as much linolic acid as any of the foregoing investigators:

[1] J. Am. Chem. Soc. 1924, **46**, 775.
[2] J. Soc. Chem. Ind. 1901, **20**, 1083.
[3] Tech. Anal. Oils, etc. London, 1914, **1**, 575, 576; **2**, 216.

Composition of Sesame Oil (Jamieson and Baughman)

	%
Glycerides of:	
Lignoceric acid	0.04
Arachidic acid	0.4
Stearic acid	4.6
Palmitic acid	7.7
Oleic acid	48.1
Linolic acid	36.8
Unsaponifiable matter	1.7
	99.34

Polarization of Sesame Oil.—Cold-pressed oil, examined by Bishop,[1] polarized +3.1° in a 200 mm. tube at 15° C., whereas hot-pressed oil polarized +7.2°. Other samples showed as high as +9°. The optically active substance is *sesamin*. Olive oil polarized +0.6° but other edible oils were levorotatory.

Lewkowitsch [2] notes that castor, croton, and rosin oils are also dextrorotatory, but these are not edible.

Samples of sesame oil examined by other observers range in polarization up to +3°, but the number of samples is too few and the data on the polarization of other oils are too meager to warrant sweeping conclusions.

Sterols.—Villavecchia and Fabris [3] were the first to show that the unsaponifiable matter of sesame oil consists of (1) *phytosterol*, (2) *sesamin*, and (3) a thick *yellow oil* which reacts in Baudouin's test. They assigned to the phytosterol the formula $C_{25}H_{44}O$. Bömer and Winter [4] considered the formula to be $C_{26}H_{44}O + \frac{1}{2}H_2O$. Heiduschka and Klamroth [5] obtained the phytosterol with a constant melting point of 136.2° to 136.8° C.

Sesamin.—The formula assigned to this substance by Villavecchia and Fabris [3] is $(C_{11}H_{12}O_3)_2$; by Tocher [6] is $C_{18}H_{18}O_5$; by Bömer and Winter [4] is $C_{33}H_{30}O_{10}$; and by Heiduschka [7] is $C_{20}H_{19}O_6$. A quantity equivalent to 0.17 per cent was separated by Heiduschka as large needles with a melting point of 122.5° C. It contained carbon 67.36 and hydrogen 5.34 per cent.

[1] J. Soc. Chem. Ind. 1887, **6**, 750.
[2] Chem. Tech. Fats, etc. London, 1914, **2**, 216.
[3] Z. angew. Chem. 1893, **6**, 505.
[4] Z. Unters. Nahr.-Genussm. 1899, **2**, 705; 1901, **4**, 873.
[5] Dissertation, München, 1911.
[6] Pharm. J. Trans. 1893, **23**, 700.
[7] Eighth Int. Cong. Appl. Chem. 1912, **11**, 13.

Kreis[1] records the following color reactions of sesamin in 0.1 per cent petroleum ether solution:

Nitric acid, also nitric + sulphuric acid	Yellow
Acetic anhydride + sulphuric acid (Bömer and Winter)	Red, then green
Pyrogallol + hydrochloric acid (Tocher)	Violet
Formaldehyde + sulphuric acid (Bellier)	Violet
Stannous chloride solution (Soltsien)	Red
Hydrogen peroxide + sulphuric acid (Kreis)	Green

Baudouin's Reaction, characterized by the red color formed on shaking the oil with hydrochloric acid and a little sugar, has been shown by Villavecchia and Fabris[2] to be due to the action of the furfural, formed by the acid and sugar, on an unknown substance contained in the yellow oil noted above. Kreis[3] believed the reacting substance is a phenol-like body. Malagnini and Armanni[4] found a crystalline substance thought to be the active principle and obtained from it a decomposition product, *oxyhydrochinon,* which was stated to be the phenol-like body of Kreis. Neither Bömer and Winter nor Heiduschka were able to isolate a crystalline substance giving a phenol reaction.

Phosphorus-Organic Compounds. *Lecithin.*—Schulze and Frankfurt[5] found 0.15 to 0.56 per cent of lecithin in sesame cake. Hebebrand[6] following the same method found 0.75 per cent in the seed.

Phytin and Nucleic Acid.—No results available.

Mineral Constituents.—The analysis of the ash of white sesame seed by Hebebrand[6] given below is characterized by the high content of lime. The location of the excessive amount of lime is largely in the epidermal cells of the spermoderm where it exists as concretions of oxalate crystals. (See Microscopic Structure.)

Analysis of Sesame Seed Ash (Hebebrand)

K_2O	Na_2O	CaO	MgO	Fe_2O_3*	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%
11.85	1.79	35.14	12.88	3.04	30.82	0.89	3.04	0.16

* Includes Al_2O_3.

Hebebrand tentatively reports 0.08 to 0.26 per cent of oxalic acid soluble in water and 0.210 to 1.821 per cent of calcium oxalate in sesame seed but notes that the method of analysis is lacking in accuracy. The defatted seed was boiled directly with water and acid respectively.

[1] Mitt. Lebens. Hyg. 1928, **19,** 385.
[2] Loc. cit.
[3] Chem. Ztg. 1903, **27,** 1030.
[4] Ibid. 1907, **31,** 884.
[5] Landw. Vers.-Stat. 1894, **43,** 307.
[6] Loc. cit.

WEEDS SEEDS OF THE PLANTAIN FAMILY

(*Plantaginaceæ*)

Belonging to this small family are two bothersome weeds, English and common plantain, the seeds, less often the whole fruit, of which occur to some extent in grain.

MACROSCOPIC STRUCTURE.—The inflorescence is in heads at the ends of long stalks (scapes) arising from a group of root leaves. The *calyx* is composed of four sepals, the *corolla* of a narrow tube and four spreading lobes. Both are inconspicuous as are also the bracts. Of special interest is the dehiscence of the several-seeded *pod* which is transverse, the top falling away and exposing the hemi-anatropous seeds. Characteristic of the *seed* is the non-starchy endosperm of horny texture, embedded in which is the straight embryo.

MICROSCOPIC STRUCTURE.—The line of dehiscence of the *pericarp* shows an interesting change from longitudinally elongated to round cells as noted under English plantain. *Mucilage cells* form the outer epiderm of the spermoderm. Thickened cell walls constitute the chief reserve material of the *endosperm*.

ENGLISH PLANTAIN SEED

Plantago lanceolata L.

Fr. Plantain lanceolé. It. Piantaggine. Ger. Spitzwegerich.

This weed, also known as narrow-leaved plantain and rib grass, although now very common in the Western Hemisphere, especially in grassland, is not a native, having been introduced in clover and other seed from Europe. It is today a common impurity of clover seed and one not easily recognized. Rarely it occurs in grain.

MACROSCOPIC STRUCTURE.—Several tough green stalks (scapes) arise from a rosette of narrow, hairy, mostly five-nerved root leaves, each bearing a brown-gray close flower head (*spike*) with projecting stamens. The *fruit* is a dry two-celled capsule opening transversely, the lower portion, together with the four scale-like *sepals*, remaining on the plant while the upper portion or lid and the small *corolla*, consisting of a tube and four spreading lobes, fall away liberating the two seeds.

Each *seed* is oval or ellipsoidal, up to 2.5 mm. long, light to dark

brown, lustrous, and has a broad groove extending nearly its entire length. In the middle of the groove is the hilum from which the raphe extends to one end. The seed is accordingly hemi-anatropous. Its shape in cross section is shown in Fig. 247, above. The embryo is straight, embedded in the non-starchy endosperm (*E*). The radicle (*R*) is longer than the cotyledons. These latter in cross section are nearly semicircular, the separation being at right angles to the longer diameter of the section.

MICROSCOPIC STRUCTURE. Corolla.—Two layers are evident in surface mounts of the lobes: (1) *wavy-walled cells* and (2) *straight-walled cells*, both more or less elongated. Only one layer is distinctly seen in the corolla tube, the cells being elongated-polygonal with radial walls that often tip over showing outer and inner surface as two distinct systems of meshes.

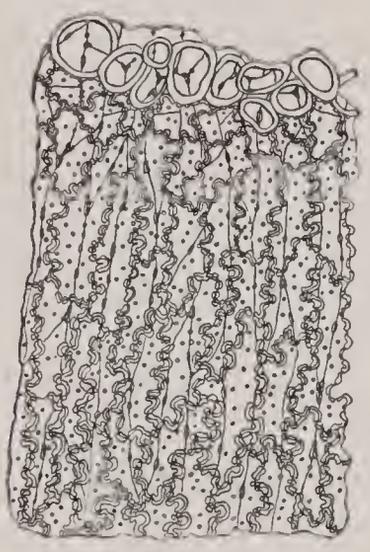


Fig. 246.

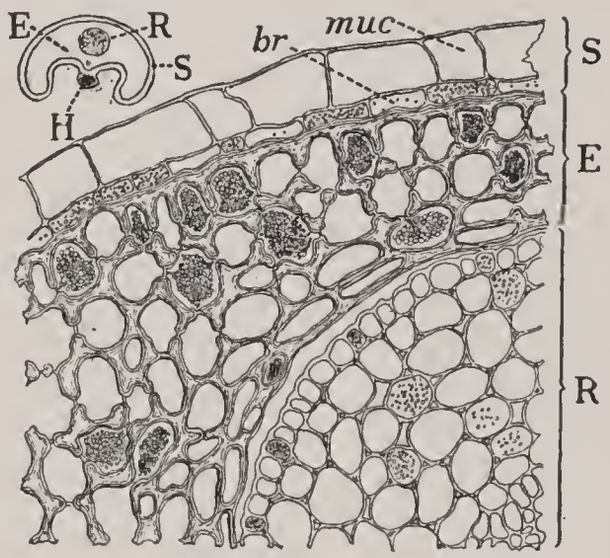


Fig. 247.

Fig. 246.—English Plantain. Inner pericarp in surface view. Endocarp of thin-walled pointed cells beneath wavy-walled sclerenchyma and, at dehiscence edge, round cells. ×160. (A.L.W.)

Fig. 247.—English Plantain. Seed in cross section. *S* spermoderm: *muc* outer epiderm of mucilage cells, *br* inner epiderm of brown cells. *E* endosperm with thick cellulose walls. *R* radicle. *H* hilum. Whole seed, ×12; portion, ×160. (A.L.W.)

Pericarp.—Kraus [1] and Harz [2] describe only three layers, the endocarp, which we find in addition, having escaped their attention. The four layers are as follows: (1) *epicarp*, the cells of which are nearly square, arranged end to end in rows except at the line of dehiscence where they are smaller and often transversely elongated, (2) *hypoderm* made up of longitudinally elongated parenchyma or spongy parenchyma cells, arranged end to end in rows, with small intercellular spaces, (3)

[1] Jahr. wiss. Bot. 1866–7, p. 83.

[2] Samenkunde. Berlin, 1885, p. 986.

sclerenchyma cells (Fig. 246), longitudinally elongated with wavy, strongly thickened porous walls except at the line of dehiscence where they are round and non-porous, and (4) *endocarp* (Fig. 246) also, of long cells but pointed, thin-walled, and faintly beaded (porous).

At maturity the first two layers are more or less obliterated except at the apex, line of dehiscence, and base, whereas at that stage the last two are most strongly developed.

Spermoderm (Fig. 247, *S*).—In cross section two layers are evident: (1) *outer epiderm* of thick mucilage cells (*muc*) and (2) *inner epiderm* (*br*) of thin-walled cells with brown contents resulting from the disorganization of the chlorophyl present during the earlier stages of development. A *middle layer* is present, even at maturity, in the groove and at the ends but on the convex side, if present at all, it is collapsed, as noted by Kraus.

Endosperm (Fig. 247, *E*).—A dense tissue with greatly thickened, sparingly porous walls and with contents giving reactions for protein and fat makes up the endosperm. It is comparable with the endosperm of ivory-nut, date stone, coffee, and persimmon.

Embryo (Fig. 247).—Both cotyledons and radicle (*R*) contain aleurone grains and fat. The *periblem* (cortex) ring of the radicle is composed of large round cells and intercellular spaces. The *plerome* cylinder is narrower. A conspicuous *procambium bundle* passes through the center of each cotyledon.

Chief Structural Characters.—Seed oval or ellipsoidal, up to 2.5 mm., hemi-anatropous with broad groove. Embryo straight in horny endosperm.

Pericarp with both elongated, porous and round, non-porous, thick-walled cells. Endosperm with reserve carbohydrate in thickened walls. Embryo of thin-walled cells containing aleurone grains and fat.

COMMON PLANTAIN

Plantago major L.

Fr. Plantain commun. Ger. Grosser Wegerich.

Broad-leaved or common plantain has smooth, mostly seven-nerved, broad leaves which when young are used as greens.

MACROSCOPIC STRUCTURE.—The head (*spike*) is green, long and narrow; the *capsule* is several- (often fifteen or more) seeded. Unlike those of English plantain the *seeds* seldom exceed 1.5 mm. and are not grooved.

MICROSCOPIC STRUCTURE.—Practically the same as of English plantain.

SEEDS OF THE COMPOSITE FAMILY

(*Compositæ*)

Sunflower, madia, and niger, the three species yielding commercial seeds and oil, also kinghead and ragweed, two common weeds, belong in the sunflower tribe (*Helianthoideæ*); thistles and burdock, which are also common weeds, belong in the widely separated thistle tribe (*Cynaroideæ*).

COMPARATIVE MACROSCOPIC STRUCTURE.—Characters of the *flowers* of the sunflower and thistle groups are too well known to require description. The dry *fruits* or achenes (Figs. 248, 259, 260 and 261), commonly known as seeds, differ in maximum length and appearance as follows: sunflower 18 mm., striped; madia 8 mm., light to dark; niger 5 mm., black; Canada thistle 3 mm., brown; bull thistle 4 mm., light; burdock 7 mm., mottled, with four teeth. Kinghead and ragweed have the achene enclosed in a leathery involucre with ribs and beaks, the whole reaching 10 mm. in kinghead and 4 mm. in ragweed.

All the species have a leathery pericarp, a thin spermoderm and endosperm, and bulky cotyledons.

COMPARATIVE MICROSCOPIC STRUCTURE.—An endosperm, of one layer of aleurone cells, and bulky cotyledons characterize all the species. A layer of black humous substance or phytomelan characterizes the sunflower tribe. The thick-walled sclerenchyma fibers beneath the phytomelan of the sunflower tribe are replaced by curious thin-walled, finely reticulated fibers in the thistle tribe. Characters of the members of each group follow:

Sunflower Tribe.—*Epicarp cells* of sunflower and madia straight, porous; of niger, straight, non-porous; of kinghead and ragweed, sinuous-walled, porous. *Hairs* on epicarp of sunflower only. *Hypoderm cells* of sunflower porous, in several rows; of madia, non-porous, in single row; of niger, rail-shaped; of kinghead and ragweed, beaker-shaped. *Fibers* of sunflower, madia, and niger large; of kinghead and ragweed, small. Outer epiderm of *spermoderm* of sunflower with zigzag walls; of madia, with straight walls; of niger, with slit-porous walls; of kinghead, with reticulated walls.

Thistle Tribe.—*Epicarp cells* of Canada thistle reach 9 μ high, outer walls 4.5 μ thick; of bull thistle 15 μ high, outer walls 7 μ thick; of burdock 70 μ high, outer walls 10 μ thick. *Endocarp* of all three species with crystals. Parallelogram cells of *spermoderm* of Canada thistle 50 μ high; of bull thistle and burdock 100 μ high. Aleurone grains of burdock largest (up to 18 μ).

COMPARATIVE CHEMICAL COMPOSITION.—The ratio of protein to fat in all three cultivated oil seeds, namely sunflower, madia, and niger, is approximately as 1 : 2.

Proteins.—Only the proteins of the sunflower have been studied and these not as exhaustively as could be desired. The chief protein is a globulin.

Oil.—The iodine number of sunflower oil ranges from 120 to 140, those of madia and niger oils are for the most part within the same limits, hence they are semi-drying oils. The chief glycerides of sunflower oil are olein 33 and linolein 57 per cent.

Ash.—Some of the ash analyses reported are from the older literature and need corroboration. In general the potash is relatively low, the lime and magnesia relatively high.

SUNFLOWER

Helianthus annuus L.

Fr. Tournesol. Sp. Girasol. It. Girasole. Ger. Sonnenblume.

The sunflower is a native of Mexico. Outside of Russia, Hungary, Egypt, and China, where it is extensively grown for food, the plant is best known as an ornamental. In India its culture on a considerable scale has not been fully satisfactory. More successful results have been obtained in South Africa.

In addition to the ornamental varieties, the Russian large-seeded type is listed in American catalogs, the seeds being grown for poultry food. In Russia the "seeds" (fruits) are eaten raw as nuts, but the principal use of the decorticated seed there and elsewhere is for oil production. Cold-pressed oil is used in Russia as a cooking fat and for the manufacture of oleomargarine; the inferior oils are utilized for soap-making and other technical purposes.

Sunflower cake is a valuable concentrated feed much used in Russia, Hungary, and Scandinavian countries.

MACROSCOPIC STRUCTURE.—The enormous *flower heads*, familiar to all, are made up of numerous fertile, yellow or brown, tubular disk flowers and a marginal circle of sterile ray flowers with large yellow ligules, all on a broad receptacle. The *achenes* are obovate up to 1.8 cm. long, flattened, more or less diamond-shaped in cross section. They are white, black, or white-and-black striped, the latter, like ribbon grass, with an infinite variety of combinations, three of which are shown in Fig. 248.

The *pericarp* is leathery with a paper-like lining within which is a

thin spermoderm and endosperm enclosing the embryo consisting largely of two fleshy cotyledons.

MICROSCOPIC STRUCTURE.—Hanausek [1] has studied not only the phytomelan layer but the development and structure of the whole pericarp including the twin hairs.

Pericarp (Fig. 249, *F*; Fig. 250). —For convenience the tissues in this, as well as in other nearly related composite achenes, are divided into five layers: (1) *epicarp* (*epi*) of longitudinally elongated cells with beaded radial walls, also twin and jointed hairs (t^1, t^2) or hair scars (*ts*, *ti*), (2) *hypoderm* (*hy*) of finely porous cells in several cork-like cell layers, (3) non-cellular dark brown or black *phytomelan layer* (*br*), (4) *fiber layer* (*f*) with fiber bundles separated by rays of thin-walled non-porous (m^1) and porous (m^2) cells, and (5) compressed *parenchyma*, including the endocarp the cells of which are indistinguishable from the others.

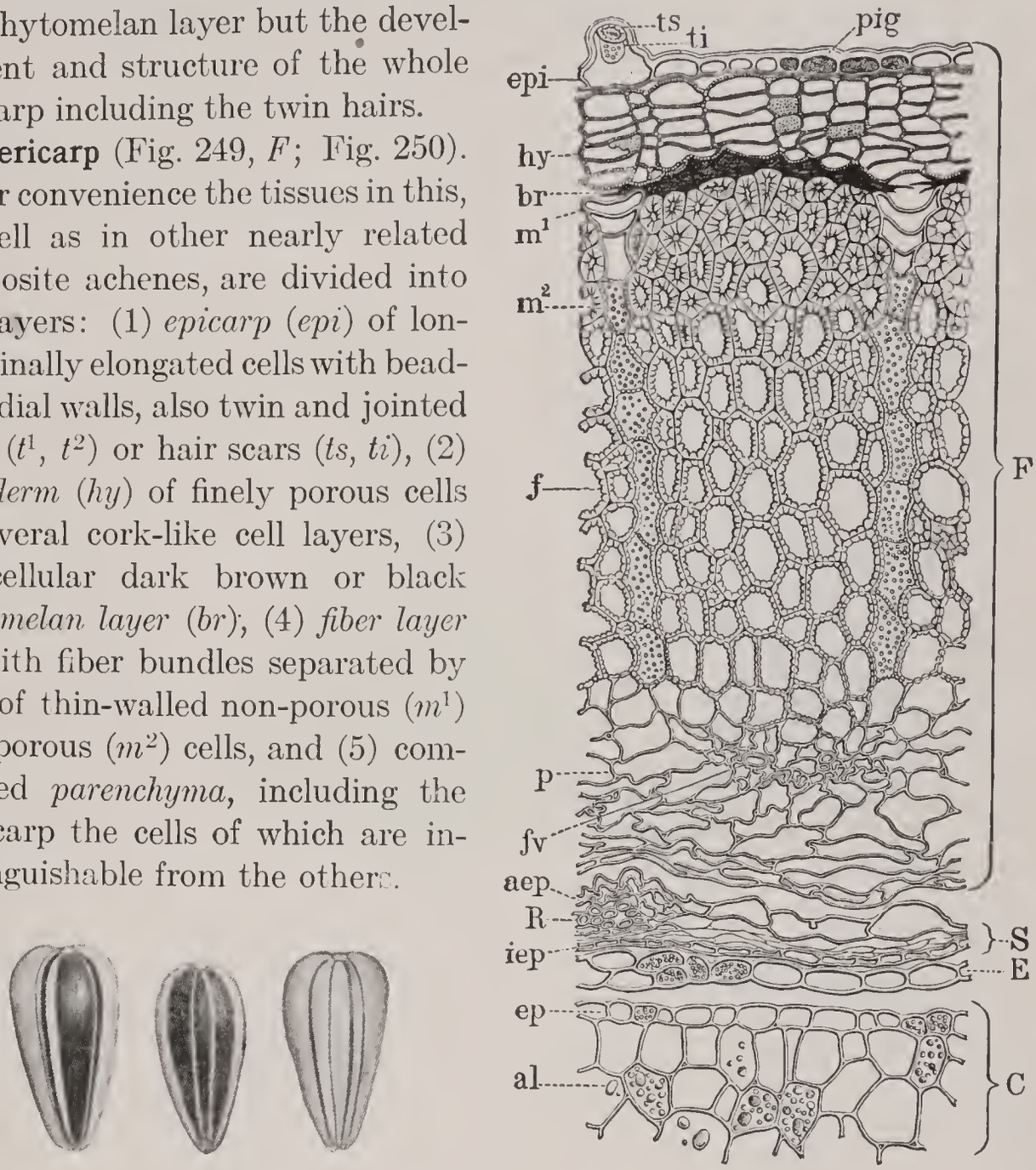


Fig. 249.

Fig. 248.

Fig. 248.—Sunflower. Achenes showing different markings. ×2. (A.L.W.)

Fig. 249.—Sunflower. Fruit in cross section. *F* pericarp: *epi* epicarp with *pig* pigment cells, also *ts* and *ti* scars of twin hairs on foot cell, *hy* hypoderm, *br* phytomelan layer, *f* fiber layer with m^1 and m^2 cells of ray between fiber bundles, *p* parenchyma with *fv* fibro-vascular bundle. *S* spermoderm: *aep* outer and *iep* inner epiderm. *R* raphe. *E* endosperm. *C* cotyledon: *ep* epiderm, *al* aleurone grains. ×160. (K.B.W.)

In black seeds or the dark stripes of striped seeds the *pigment* (*pig*) is located in the epicarp, some of the cells being uniformly colored while others are entirely free from color.

[1] B. deut. bot. Ges. 1902, **20**, 449.

Hanausek, in his paper on the development of the pericarp, points out the peculiar nature of the *twin hairs* which are not only grown together side by side but are joined at the base to a projecting foot cell, one at the top, the other at the side, the two scars of such twins being shown in Fig. 249, *ts* and *ti*.

Two kinds of cells make up the *rays* separating the fiber bundles. The two or three outer cells (Fig. 249, m^1) are non-porous, forming together in cross section an urn-shaped design, the remainder (Fig.

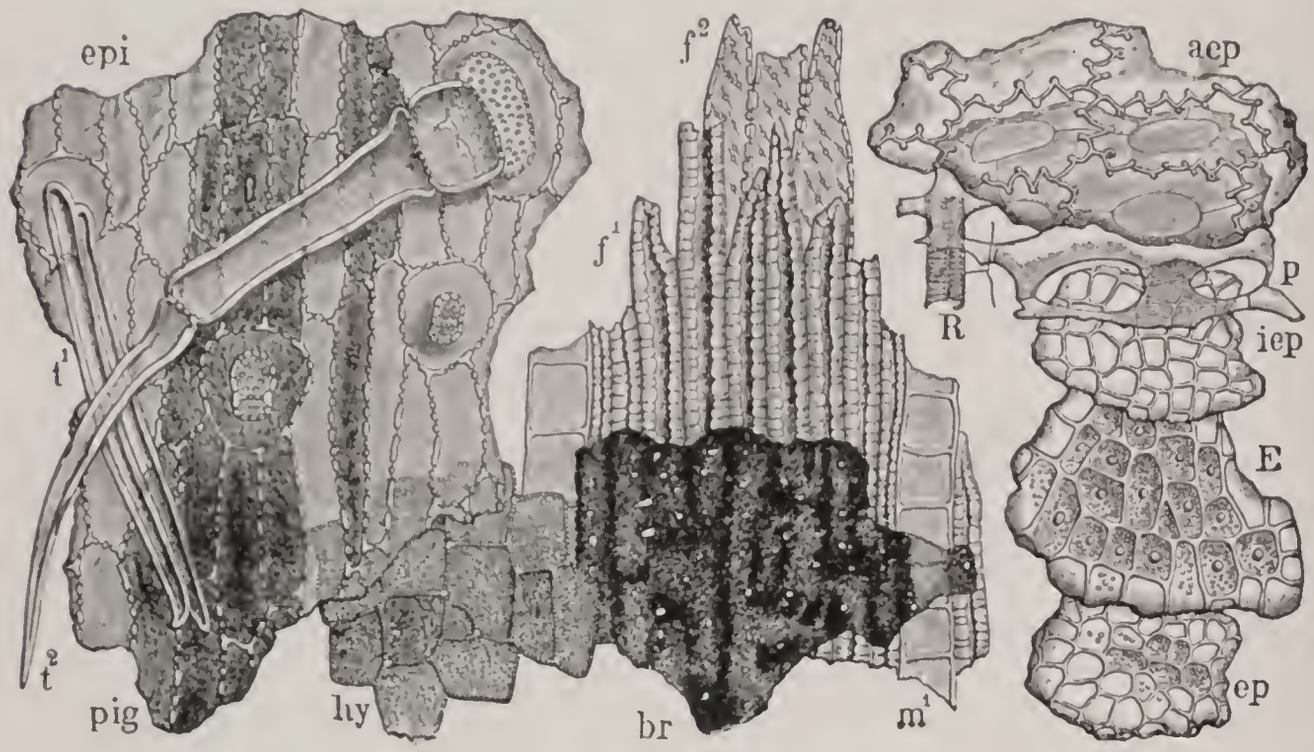


Fig. 250.—Sunflower. Elements of fruit in surface view. Pericarp: *epi* epicarp with *pig* pigment cells, t^1 twin hairs, and t^2 jointed hairs; *hy* hypoderm; *br* phytomelan layer; f^1 outer and f^2 inner fibers; m^1 outer cells of ray between fiber bundles. Spermoderm: *aep* outer epiderm; *p* spongy parenchyma; *iep* inner epiderm. *R* raphe. *E* endosperm. *ep* outer epiderm of cotyledon. ×160. (K.B.W.)

249, m^2) are porous, transversely flattened, appearing narrow in radial and tangential sections.

Adjoining every other fiber bundle, within the parenchyma, is a small *fibro-vascular bundle* (*fv*).

Spermoderm (Fig. 249, *S*; Fig. 250).—Little detail is evident in cross section. In surface view three layers are seen: (1) *outer epiderm* (*aep*) of transversely elongated cells with zigzag walls, (2) *spongy parenchyma* (*p*) through which runs the raphe (*R*), and (3) *inner epiderm* (*iep*) of small polygonal cells.

The zigzag walls of the *outer epiderm* are highly characteristic. At each angle is a peculiar thickening, in some places forming a loop.

Endosperm (Figs. 249 and 250, *E*).—A single, occasionally a double, layer of *aleurone cells* lies between the spermoderm and the embryo. In each a nucleus and numerous aleurone grains are evident.

Embryo.—The cotyledons in cross section (Fig. 249, *C*) are seen to have isodiametric cells beneath the *outer epiderm* (*ep*) and several rows of palisade cells beneath the inner epiderm. Numerous aleurone grains (*al*) up to 14 μ and fat fill the cells.

Chief Structural Characters.—Achenes obovate, large (1.8 cm.), white, black, or striped.

Epicarp beaded, often with dark contents; hairs twin and jointed; nypoderm cork-like, porous; phytomelan over large bundles of large fibers. Spermoderm with outer epiderm of zigzag-walled cells. Endosperm of aleurone cells mostly in single layer. Embryo containing aleurone grains (14 μ) and fat.

Composition of Sunflower Seed

	Part analyzed *	Water	Protein	Fat	N-f.ext.	Pento-sans	Fiber	Ash
	%	%	%	%	%	%	%	%
Whole seed:								
Kosutany...	100	0.00	15.98	36.60	19.39	.....	24.30	3.13
Windisch								
Min.....	100	3.37	13.52	22.21	13.37	.....	23.48	2.63
Max.....	100	12.85	19.11	36.51	21.26	.....	32.27	4.14
Aver.....	**100**	**6.88**	**15.19**	**28.29**	**17.36**		**28.54**	**3.20**
Hulls:								
Kosutany...	42	9.02	5.16	5.17	23.92	.....	54.95	1.78
Kilgore.....	53	10.00	3.75	1.56	27.52	.....	54.86	2.31
Kilgore.....	54	10.50	4.37	3.41	22.10	.....	57.00	2.62
Pieraerts								
Eala.....	.....	8.54	4.00	0.67	33.34	22.56	51.01	2.44
Nioka....	.....	8.86	3.31	0.82	29.61	18.56	54.93	2.47
Kernels:								
Kosutany...	58	14.70	24.95	49.62	4.18	.....	3.28	3.27
Kilgore.....	47	6.90	29.36	43.92	13.02	.....	2.64	4.16
Kilgore.....	46	6.85	31.57	41.75	15.93	.....	2.50	1.40
Windisch								
Min.....	45	2.89	23.28	35.12	7.43	.....	2.30	3.66
Max.....	60	6.87	26.71	55.55	27.02	.....	4.30	4.29
Aver.....	.....	**4.00**	**24.93**	**50.44**	**12.83**	.....	**3.14**	**4.01**
Pieraerts								
Eala.....	.....	5.97	32.81	40.85	10.95	3.33	3.66	5.76
Nioka....	.....	6.36	32.94	48.36	3.95	2.83	4.29	4.10

* In whole fruit.

CHEMICAL COMPOSITION.—Kosutany [1] of the Experiment Station at Altenburg, Hungary, reporting on sunflower seed cake to the Association of German Experiment Stations, gave his own analyses of the whole (unextracted) seed, hulls, and kernel, also a compilation of analyses of the press cake. Kilgore [2] analyzed the kernels and hulls of two varieties, Mammoth Russian and Black Giant, and compared the results with those for cottonseed. Windisch, nearly ten years later,[3] reported analyses of the whole seed and of the kernel. Pieraerts [4] analyzed the kernels and hulls of a sample of Russian sunflower grown at the Eala Botanic Gardens and of Hungarian sunflower grown at the Nioka experimental farm, both in the Belgian Congo. A summary of results by the authors named is shown on the preceding page.

Sunflower Cake varies greatly in composition owing to the amount of hulls present and the extent to which the oil has been removed, as illustrated by the following maximum and minimum results of a compilation by Kosutany,[1] excluding 3 samples with high water content (36.84 to 44.31 per cent).

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	3.11	16.38	4.90	10.04	6.05	4.91
Max.	15.18	47.96	29.58	28.62	23.58	11.27

Proteins.—Osborne and Campbell [5] made and analyzed several preparations of a globulin but were unable to remove completely "helianthotannic acid." Their purest preparation was a globulin containing: carbon 51.54, hydrogen 6.99, nitrogen 18.58, sulphur 1.00, and oxygen 21.71 per cent, calculated free of 0.47 per cent of ash. They concluded that the globulin is identical with the *edestin* of other oil seeds.

Amino Acids of Edestin.—Abderhalden and Reinbold [6] isolated after hydrolysis the percentages of amino acids shown on the following page.

Jones, Gersdorff, and Moeller [7] report 1.56 per cent of cystine and 2.54 per cent of tryptophane in sunflower seed globulin.

[1] Landw. Vers.-Stat. 1893, **43**, 253.
[2] N. Carolina Agr. Exp. Sta. 1893, Bul. **90b**.
[3] Landw. Vers.-Stat. 1902, **57**, 305.
[4] Mat. grass. 1926, **18**, 7447.
[5] J. Am. Chem. Soc. 1897, **19**, 487.
[6] Z. physiol. Chem. 1905, **44**, 284.
[7] J. Biol. Chem. 1924, **62**, 183.

PRODUCTS OF HYDROLYSIS OF SUNFLOWER EDESTIN (ABDERHALDEN AND REINBOLD)

	%
Glycocoll	2.5
Alanine	4.5
Valine	0.6
Leucine	12.9
Serine	0.2
Aspartic acid	3.2
Glutamic acid	13.0
Tyrosine	2.0
Phenylalanine	4.0
Proline	2.8
Tryptophane	+
	45.7

Nitrogen Distribution in Sunflower Seed.—Nollau [1] applied Van Slyke's method directly to the ground seed with the following results:

	%
Humin N	5.73
Cystine N	2.98
Arginine N	16.80
Lysine N	4.86
Histidine N	4.56
Mono-amino N	45.32
Non-amino N	5.27
Amide N	15.42
Total N	100.94

Oil.—The manufacture and consumption of sunflower oil has until recent years been largely confined to Russia, Hungary, India, and China, where it is used for human food and for the manufacture of paints and varnishes. The industry has proved successful in South Africa but not in the United States.

The oil has drying characters that place it in the class with linseed, poppy, hempseed, walnut, and some other oils.

Physical and Chemical Values.—The range in the ordinarily determined values, compiled from various sources, follows:

	Sp. gr. 15.5° C.	Refractive index 25° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer
						° C.
Min	0.920	1.4714	68	188	120	17
Max	0.926	1.4735	75	194	140	18

[1] J. Biol. Chem. 1915, **21**, 611.

These figures should be regarded as tentative, as the oil from some sources falls well without these limits. Tolman and Munson [1] in two oils obtained as follows: specific gravity at 15.5° C. 0.9205 and 0.9201, refractive index at 25° C. (recalculated) 1.4702 and 1.4699, and iodine number 108.3 and 104.1, which correspond closely to the results of Bolton and Revis [2] on a single sample, namely, refractive index at 25° C. (recalculated) 1.4701 and iodine number 106.

Jamieson and Baughman [3] in the sample used for determining the individual fatty acids report the following results:

Values of Sunflower Oil (Jamieson and Baughman)

Specific gravity 25°/25°	0.9193
Refractive index at 20° C.	1.4736
Saponification number	188.0
Iodine number (Hanus)	130.8
Reichert-Meissl number	0.27
Polenske number	0.25
Acetyl number	14.5
Saturated acids (determined)	7.4%
Iodine number of last	5.0
Unsat. acids and unsapon. matter (determined)	87.5%
Iodine number of last	147.5
Iodine number of unsaturated acids	147.9
Saturated acids (corrected)	7.1%
Unsaturated acids (corrected)	86.6%
Acid number	2.3
Unsaponifiable matter	1.2%
Iodine number of last	124.8

Cholesterol.—Frankfurt [4] found 0.08 per cent of cholesterol in the whole seed.

Composition of Sunflower Oil.—As found by Jamieson and Baughman [3] the oil contains:

Glycerides of:	%
Lignoceric acid	0.4
Arachidic acid	0.6
Stearic acid	2.9
Palmitic acid	3.5
Oleic acid	33.4
Linolic acid	57.5
Unsaponifiable matter	1.2
	99.5

[1] U. S. Dept. Agr., Bur. Chem. 1903, Bul. **77**, 40.
[2] Fatty Foods. Philadelphia, 1913, p. 238.
[3] J. Am. Chem. Soc. 1922, **44**, 2952.
[4] Landw. Vers.-Stat. 1893, **43**, 166.

Carbohydrates.—Frankfurt [1] found 2.13 per cent of *sucrose* and soluble carbohydrates in the whole seed.

Pieraerts [2] determined the *pentosans* with the results given in the general table of composition above.

Phosphorus-Organic Compounds.—Frankfurt [1] found 0.51 per cent of "*nuclein* etc.," and 0.23 per cent of *lecithin* in the whole seed.

Enzymes.—Results by Traetta-Mosca and Milletti [3] show that sunflower seed contains *lipases* which increase in activity on germination. They exert their greatest influence after removal of the oil. Synthetic action, whereby oleic acid and glycerol are combined, was noted in both germinated and defatted seeds.

Mineral Constituents.—A complete ash analysis by Schädler [4] and recalculated determinations of the principal ash constituents by André [5] follow:

Analysis of Sunflower Seed Ash

	K_2O	Na_2O	CaO	MgO	Fe_2O_3*	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
Schädler....	16.23	7.41	7.63	12.29	1.60	35.53	2.34	14.65	2.42
André.....	24.89	.....	8.86	10.54	.....	24.00	9.92		

* Includes Al_2O_3.

The high content of lime and magnesia compared with that of potash may be due to the hulls. Analyses of the decorticated seed are not available.

Minor Mineral Constituents. *Iron.*—Seed 34 mg. per kilo, dry basis (McHargue).[6]

Manganese.—Seed 23 mg. per kilo, dry basis (McHargue).[6] Seed 12.20 mg. per kilo, dry basis (Quartaroli).[7]

Copper.—Seed 19.80 mg. per kilo, dry basis (Quartaroli).[7]

Zinc.—Seed 11.4 mg. per kilo, dry basis (Bertrand and Benzon).[8]

[1] Loc. cit.
[2] Loc. cit.
[3] Ann. chim. appl. 1923, **13**, 270.
[4] Tech. Fette, quoted by Kosutany, loc. cit.
[5] Bul. soc. chim. 1919, **25**, 610.
[6] J. Agr. Res. 1923, **23**, 395.
[7] Ann. chim. appl. 1928, **18**, 47.
[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

MADIA

Madia sativa Mol.

Fr. Madi. Sp. Madi. It. Madia. Ger. Madia.

Tarweed is a generic term for the species of *Madia*, all of which are natives of the Pacific slope of North and South America. Before the Spanish conquest common tarweed (*M. sativa*) was grown in Chile for its seed from which an edible oil was pressed. It was known by the aborigines as madi. A variety of the same species grows in sheep pastures in California. In America and Europe, especially in Germany and Austria, the plant has been cultivated to some extent, the cold-pressed oil having been used as a food and the inferior grades for technical purposes. Its culture and utilization outside its habitat, however, scarcely went beyond the experimental stage and are now largely abandoned.

MACROSCOPIC STRUCTURE.—The plant is glandular (hence the name "tarweed") with yellow inconspicuous ray flowers. It is night blooming. The *achenes* are slender, four- to five-angled, somewhat curved, 4 to 8 mm. long, and they vary in color from light to nearly black. Harz [1] states that the *seed* shortly before maturity is black but the color often bleaches later to gray.

MICROSCOPIC STRUCTURE.—As is often true of plant novelties, considerable attention has been given to the scientific characters of this fruit, including the histology. It is described in the treatises and in a special article by Winton.[2]

Pericarp (Fig. 251, *F*; Fig. 252).—There are five layers, not including the endocarp which at maturity is so compressed as not to show cell structure: (1) *epicarp* (*ep*) of longitudinally elongated porous cells with cuticle, (2) *hypoderm* (*hy*) of thin-walled parenchyma, (3) non-cellular dark brown or black *phytomelan layer* (*br*), (4) *fiber bundles* (*f*) separated by parenchyma rays (*m*), and (5) *parenchyma* (*p*), more or less compressed.

The *phytomelan layer* has numerous minute holes in longitudinal rows corresponding to projections on the underlying fibers, also transverse marbling.

Spermoderm (Figs. 251 and 252, *S*).—The tissue is thin-walled *parenchyma*, more or less compressed, forming only one or two distinct rows except about the raphe.

At the base of the seed are curious *porous cells* (*sc*) not apparently belonging to the raphe.

[1] Samenkunde. Berlin, 1885, p. 855.

[2] Connecticut Agr. Exp. Sta. Rep. 1903, p. 190.

Endosperm (Figs. 251 and 252, *E*).—*Aleurone cells* of the usual type form one layer.

Embryo.—The fleshy cotyledons (Fig. 251, *C*) contain aleurone grains (*al*) up to 6 μ and fat. Beneath the *outer epiderm* the cells are isodiametric; beneath the *inner epiderm* they are typical *palisade cells* in three or four layers.

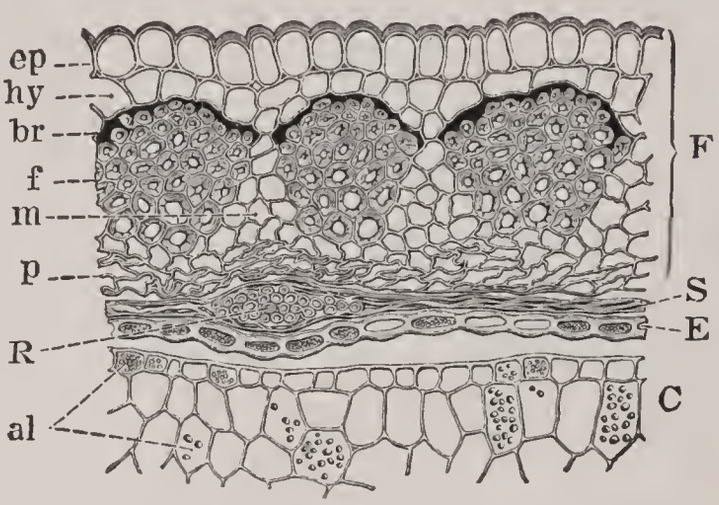


Fig. 251.—Madia. Fruit in cross section. *F* pericarp: *ep* epicarp, *hy* hypoderm, *br* phytomelan layer, *f* fiber bundles, *m* parenchyma rays, *p* parenchyma. *S* spermoderm. *R* raphe. *E* endosperm. *C* cotyledon with *al* aleurone grains. ×160. (A.L.W.)

Chief Structural Characters.—Achenes obovate, 8 mm., gray or black.

Epicarp walls beaded, hairs absent; hypoderm a single parenchyma layer; fibers and fiber bundles smaller than in sunflower, larger than in niger. Spermoderm characterless. Endosperm and embryo with smaller aleurone grains (8 μ) than in sunflower.

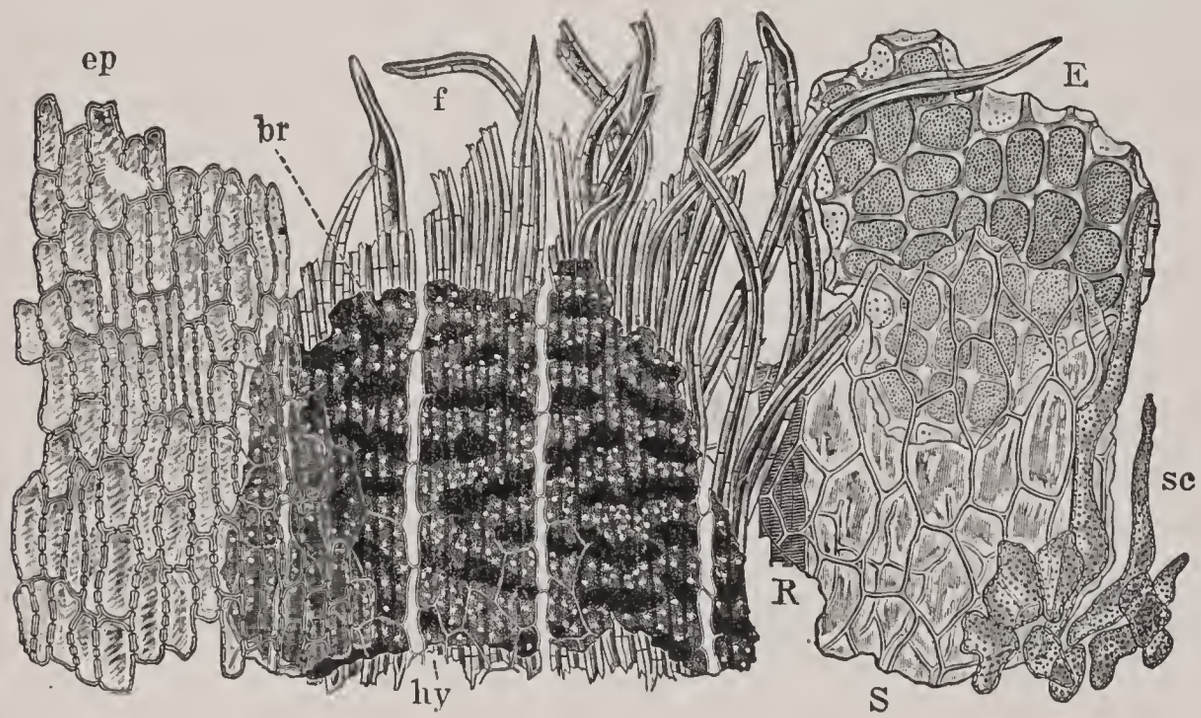


Fig. 252.—Madia. Elements of fruit in surface view. Pericarp: *ep* epicarp, *hy* hypoderm, *br* phytomelan layer, *f* fiber bundle. *S* spermoderm. *R* raphe. *sc* porous cells at base of seed. *E* endosperm. ×160. (A.L.W.)

CHEMICAL COMPOSITION.—An analysis of the whole seed was recorded as early as 1845 in Boussingault's "Die Landwirthschaft"[1] and from then to 1870 other analyses of the seed and cake appeared in

[1] 3, 202.

the literature but in recent years only one analysis [1] has been brought to the writers' notice. The following table includes Boussingault's results and the averages as given in König's Compilation and Böhmer's Kraftfuttermittel:[2]

Composition of Madia Seed and Cake

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Seed:						
Boussingault....	8.40	22.90	41.00	5.00	18.00	4.70
König (aver.)...	7.46	19.36	38.44	12.78	17.69	4.27
Cake:						
Böhmer (aver.)..	10.55	31.76	10.99	16.87	22.45	7.38

Oil.—Madia oil has less pronounced drying properties than sunflower and niger oils. Although edible when cold pressed, its chief use is for burning, soap-making, and lubrication.

The *Physical and Chemical Values*, commonly given in the treatises, are largely those of De Negri and Fabris as follows:

Values of Madia Oil

	Sp. gr. 15.5° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, titer
					° C.
Min....	0.926	.....	.....	117.5	20
Max....	0.929	96	192.8	119.5	22

The constituent fatty acids are stated to be linolic, with smaller amounts of oleic, linolenic, and isolinolenic, but no investigation has been recently attempted.

Mineral Constituents.—An early analysis by Souchay [3] showing a questionably high soda content follows:

Analysis of Madia Seed Ash (Souchay)

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5
%	%	%	%	%	%
9.53	11.24	7.74	15.42	1.08	54.99

[1] Bul. Imp. Inst. 1915, **13**, 344; Chem. Abs. **10**, 396.

[2] Berlin, 1903, p. 462.

[3] Wolff: Chem. Forsch. 1847, p. 331; Harz: Samenkunde. Berlin, 1885, p. 856.

NIGER SEED

Guizotia abyssinica (L.) Cass. = *G. oleifera* D. C. = *Verbesina sativa* Roxb.

Fr. Niger. It. Niger. Ger. Nigersamen.

Although believed to be a native of East Africa, the niger plant is now extensively cultivated in India, where it is known also as ramtil or gingelli. Its culture has been attempted in Germany and is successfully practiced in Florida.

Niger oil is pressed from the seed in India, France, and England. Cold pressed, the oil is nutty and furnishes the poor classes in India a valuable food. The second pressings are used as soap stock, lamp oil, and lubricant.

Niger cake is used chiefly in England as a concentrated fodder.

MACROSCOPIC STRUCTURE.—The flower heads have yellow ray flowers with three-toothed ligules and a leaf-like *involucre*. Each of the numerous black *achenes* of the sunflower type is but 5 mm. or less long and 1.5 mm. across at the widest part.

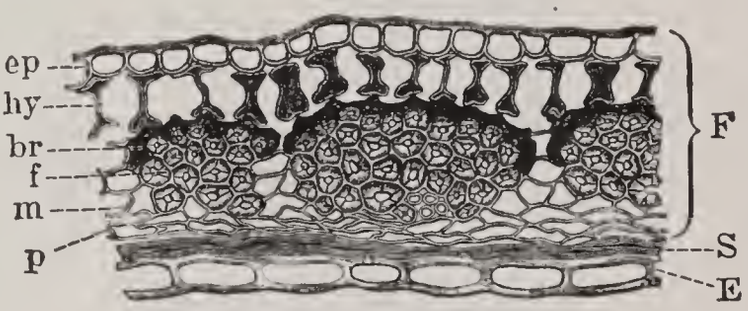


FIG. 253.—Niger. Shell in cross section. *F* pericarp: *ep* epicarp, *hy* hypoderm, *br* phytomelan layer, *f* fiber bundles, *m* parenchyma rays, *p* parenchyma. *S* spermoderm. *E* endosperm. ×300. (A.L.W.)

MICROSCOPIC STRUCTURE.—Madia and niger appear to be classed together—at least the authors who have studied one have also studied the other.[1]

Pericarp (Fig. 253, *F*; Fig. 254).—As in sunflower and madia there are five layers, the obliterated endocarp being included in the fifth: (1) *epicarp* (*ep*) of much-elongated cells without pores, (2) *hypoderm* (*hy*) of rail-shaped cells containing a dark pigment, (3) non-cellular dark brown or black *phytomelan layer* (*br*), (4) *fiber bundles* (*f*) separated by *parenchyma rays* (*m*), and (5) *parenchyma* (*p*) more or less collapsed.

The *phytomelan layer* has cross markings nearer together than in madia, which it otherwise resembles.

Spermoderm (Fig. 253 and 254, *S*).—Only one layer is conspicuous and this only in surface view—the *outer epiderm* with wavy walls and narrow elongated pores. These latter usually extend at right angles to the walls but because of the sinuous nature of the walls have a curious fan-shaped arrangement. The *inner parenchyma* tissue is compressed and inconspicuous.

[1] Winton: Connecticut Agr. Exp. Sta. Rep. 1903, p. 175.

Endosperm (Figs. 253 and 254, *E*) **and Embryo.**—As in sunflower.

Chief Structural Characters.—Achenes obovate, small (5 mm.), black.

Epicarp non-porous, hairs absent; hypoderm cells rail-shaped. Spermoderm with wavy walls and elongated pores. Otherwise similar to madia.

CHEMICAL COMPOSITION. Seed and Cake.—Since neither the seed nor the cake has entered regularly into international commerce, scanty details of their composition are available.

The first analysis of the seed reported in the literature by Anderson [1] is also the most complete. This analysis, together with the average of

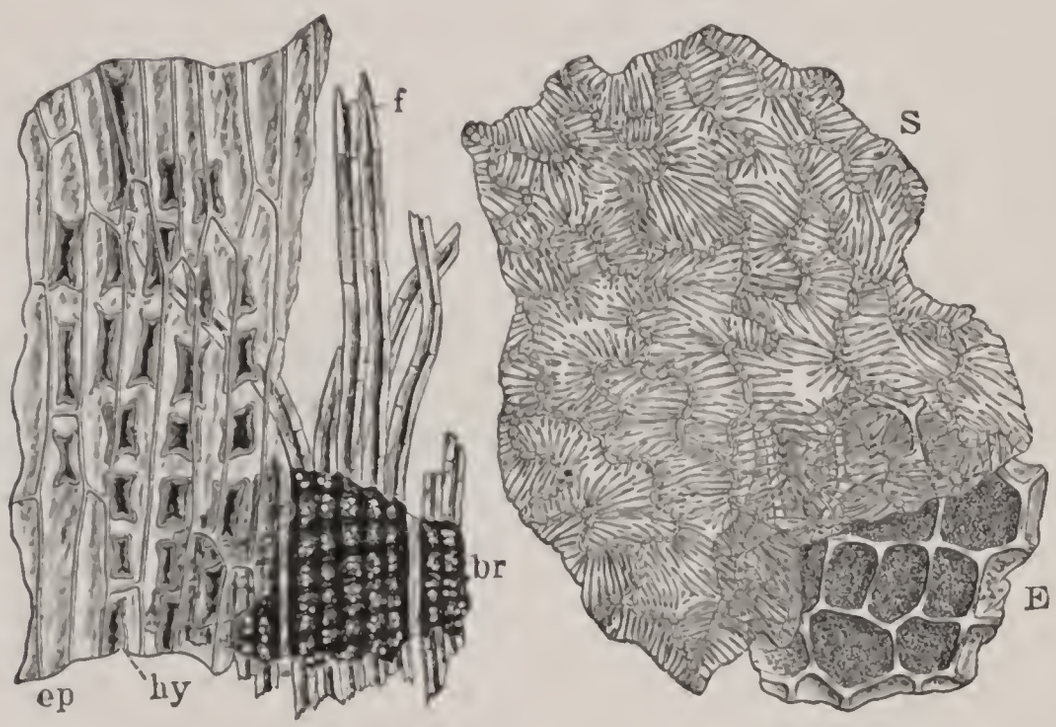


Fig. 254.—Niger. Elements of fruit in surface view. Pericarp: *ep* epicarp, *hy* hypoderm, *br* phytomelan layer, *f* fiber bundle. *S* spermoderm. *E* endosperm. ×300. (A.L.W.)

7 analyses of the cake compiled by Dietrich and König,[2] an analysis evidently of Indian cake published in the Bulletin of the Imperial Institute,[3] an analysis by Hansen,[4] and one by Smetham [5] are given in the table below.

Niger Oil has been pressed in England and France from seeds shipped from India or Africa, but the production and use of the oil are largely confined to the regions of origin. Cold-pressed oil is edible. The poorer

[1] Trans. Highl. Soc. 1860.
[2] Zusammens. Verd. Futterm. 1891.
[3] 1916, **14**, 88; Chem. Abs. **10**, 2410.
[4] Mitt. deut. Landw. Ges. 1911, **26**, 396, 412, 425; Exp. Sta. Rec. **26**, 267.
[5] Roy. Lancash. Agr. Soc. J. 1909, 28; Analyst 1910, **35**, 54.

Composition of Niger Seed and Cake

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Niger seed:						
Anderson	7.02	19.37	43.22	12.37	14.33	3.48
Niger cake:						
Dietrich and König	10.81	32.02	5.46	23.53	19.57	8.61
Bul. Imp. Inst.	10.4	33.1	6.1	23.4	16.8	10.2
Hansen	10.76	31.00	3.15	29.83	14.65	10.61
Smetham	8.90	34.06	14.03	21.80	9.26	11.95

grade of hot-pressed oil is used for lighting, soap-making, and lubrication.

Physical and Chemical Values.—The limits given in the following table are compiled from results by Crossley and Le Sueur,[1] Utz,[2] Mitchell,[3] and others:

Values of Niger Oil

	Sp. gr. 15.5° C.	Refractive index 25° C.	Maumené No.	Saponification No.	Iodine No.	Fatty acids, m. pt.
						° C.
Min	0.924	1.4741	81	188	126	25
Max	0.927	1.4762	82	193	134	29

KINGHEAD

Ambrosia trifida L.

Giant or great ragweed or kinghead, an American plant, like its near relative common ragweed (*A. artemesiæfolia* L.), grows in the state of nature in bottom land and as a weed in moist grain fields, barnyards and other wet places. It appears to be particularly troublesome in the Northwest, especially, according to Wilson,[4] along the Red River, which forms the boundary between Minnesota on the east and North Dakota and part of South Dakota on the west, these three states being the most important of the Spring wheat section.

[1] J. Soc. Chem. Ind. 1898, **17**, 991.
[2] Chem. Rev. Fett-Harz Ind. 1911, **18**, 106.
[3] Allen's Com'l. Org. Anal. 4th Ed., **2**, 70.
[4] Minnesota Agr. Exp. Sta. 1906, Bul. **95**, 226.

The name " kinghead," referring to the resemblance of the involucre to a crowned head, is current in that section as well as in shipping centers for Spring wheat, whereas the name giant or great ragweed is elsewhere more generally used.

FIG. 255.—Kinghead. Involucre enclosing fruit. I with five ridges and beaks; II with ten ridges and beaks. ×2. III cross section showing involucre (gray) with two fiber bundles in each ridge, pericarp (dark gray), spermoderm (white), endosperm (black), and cotyledons. ×4. (A.L.W.)

MACROSCOPIC STRUCTURE.—All the ragweeds are monœcious, the sterile flowers being borne above in heads, the fertile flowers below, singly or in small groups. Each *fertile flower* consists merely of a pistil in a closed pointed involucre with usually four to six (sometimes a double number) of ribs, each ending in a horn, the whole ripening into the curious one-seeded false

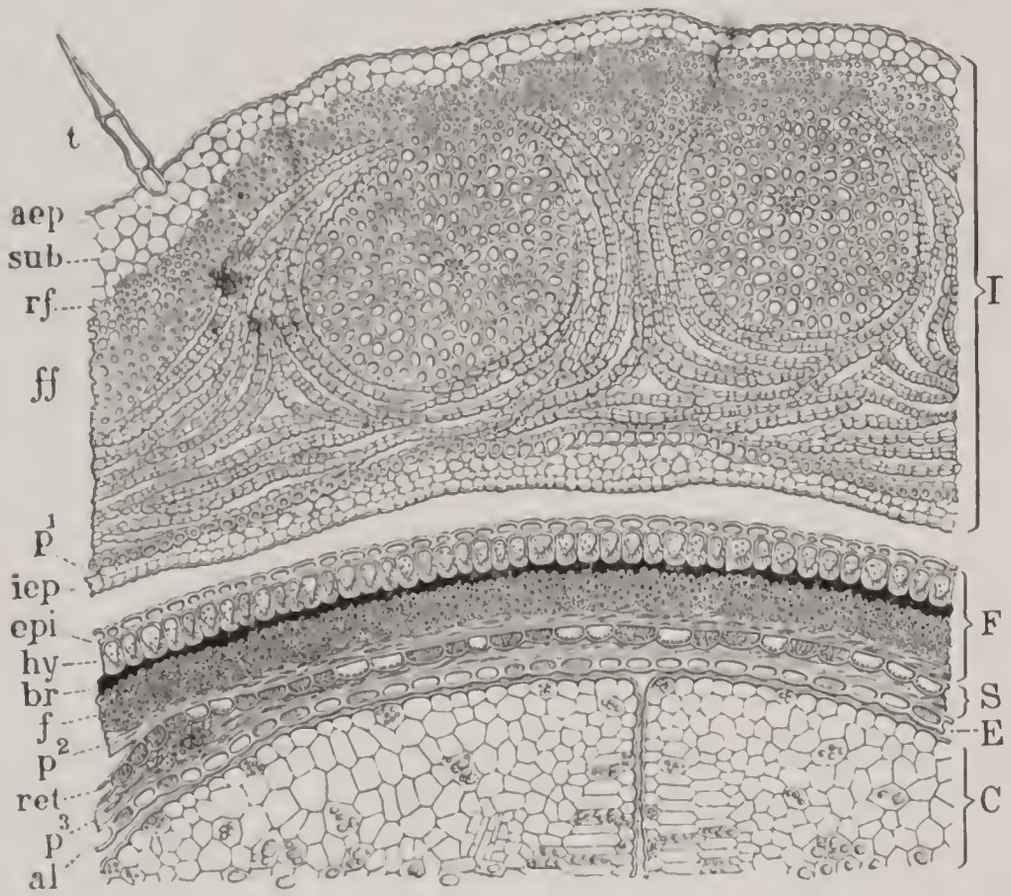


FIG. 256.—Kinghead. Fruit in cross section. I involucre: *aep* outer epiderm with *t* jointed hair, *sub* parenchyma, *rf* reticulated fibers, *ff* bast fiber zone with two longitudinal bundles, p^1 spongy parenchyma, *iep* inner epiderm. *F* pericarp: *epi* epicarp, *hy* hypoderm of beaker-shaped stone cells, *br* phytomelan layer, *f* fiber zone, p^2 obliterated parenchyma. *S* spermoderm: *ret* reticulated cells, p^3 obliterated parenchyma. *E* endosperm: *al* aleurone cells. *C* cotyledons with aleurone grains. ×120. (A.L.W.)

fruit reaching 1 cm. in length, that suggested the name "kinghead"

(Fig. 255). When double the normal number of ribs is present, the horns into which the secondary ribs pass are smaller than the others and form a more or less pronounced inner row. Each primary rib, whether or not secondary ribs are present, contains two main bundles, each secondary rib only one. In addition to the main bundles, small ones, visible under the microscope, may be present in both main and secondary ribs.

The *fruit* (achene) is free in the involucre; the pericarp, spermoderm, and endosperm form a thin black shell in which is the embryo with two fleshy cotyledons.

MICROSCOPIC STRUCTURE.—The ragweeds, being American plants not as yet very common in the Old World, have been ignored by

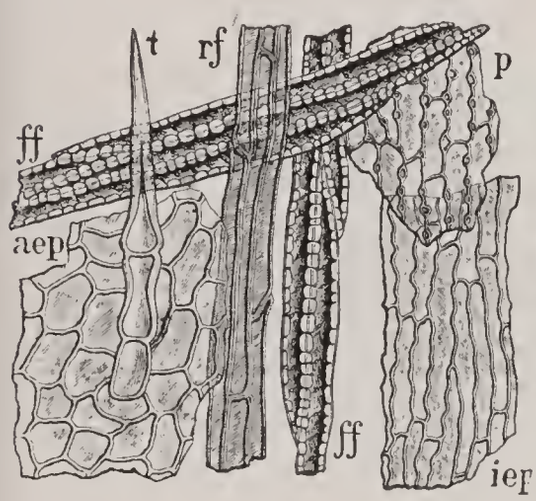


Fig. 257.

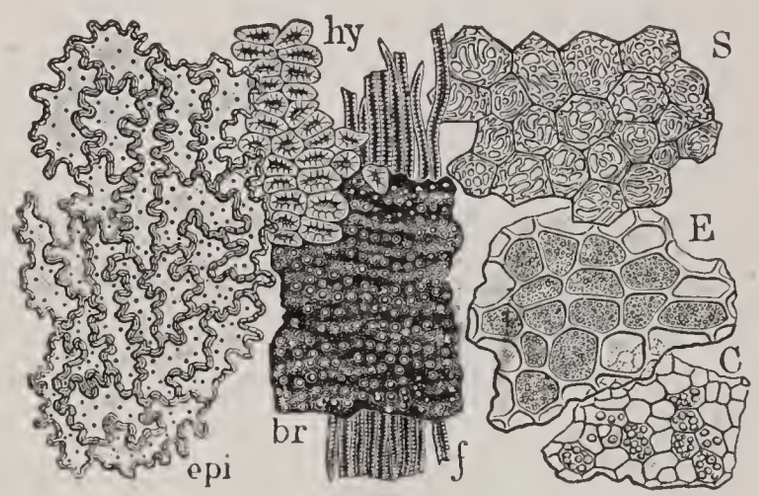


Fig. 258.

Fig. 257.—Kinghead. Involucre in surface view: *aep* outer epiderm with *t* jointed hair, *rf* reticulated fibers, *ff* bast fibers, *p* spongy parenchyma, *iep* inner epiderm. ×160. (A.L.W.)

Fig. 258.—Kinghead. Elements of fruit in surface view. Pericarp: *epi* epicarp, *hy* hypoderm, *br* phytomelan layer, *f* fibers. *S* reticulated cells of spermoderm. *E* endosperm. *C* epiderm of cotyledon. ×160. (A.L.W.)

histologists excepting Hanausek who, as noted below, merely refers to the non-cellular black layer.

Involucre (Fig. 256, *I*; Fig. 257).—The structure is particularly interesting in its mechanical tissues. Six different layers are seen in cross section: (1) *outer epiderm* (*aep*) made up of irregularly polygonal cells and jointed hairs (*t*), (2) *subepidermal layer* (*sub*) of characterless parenchyma, one to several cells thick, (3) finely *reticulated fibers* (*rf*) with thin walls, (4) *bast fibers* (*ff*) variously arranged with two fiber bundles, (5) *spongy parenchyma* (*p*, p^1) of longitudinally elongated cells, and (6) *inner epiderm* (*iep*) of longitudinally elongated wavy-walled cells.

The fourth layer of *bast fibers* is not of uniform structure. In the outer rows and in the extreme inner row the fibers run longitudinally, whereas between they run transversely except about the bundles where they form remarkable concentric curves. In the inner row, within the pair of bundles, they pass into elongated cells.

Bast fibers apparently make up the entire mass of the bundle.

Pericarp (Fig. 256, *F*; Fig. 258).—Five layers are evident: (1) *epicarp* (*epi*) of moderately thickened, porous, sinuous-walled cells, (2) *hypoderm* (*hy*) of beaker-shaped stone cells, 20 μ high (3) non-cellular *phytomelan layer* (*br*) of carbon-like substance with minute holes, (4) *fiber layer* (*f*), the individual fibers, several thick, being narrow with numerous minute pores, and (5) compressed *parenchyma* (p^2) including the endocarp which, because of the compression, is not recognizable. Medullary rays are absent.

Hanausek,[1] in his classical monograph on the phytomelans of the *Compositæ*, does not give a special description of this species but notes that the formation agrees closely with that in *Xanthium* and refers to his earlier studies [2] of *X. strumarium* L. and *X. spinosum* L. in which he found two of these layers, one outside, the other inside of the thin-walled, radially elongated cells of the hypoderm. In both species the outer layer adjoins the epicarp, the inner layer adjoins the bast fibers, which are very narrow, forming a closed coat; furthermore the hypoderm is one-rowed, whereas in *X. macrocarpum* D.C. it is two-rowed. Hanausek's photomicrographs [2] of the phytomelan layers in surface view, of the first two species of *Xanthium* mentioned above, have much the same appearance as the layer in kinghead.

Spermoderm (Figs. 256 and 258, *S*).—Only one distinct layer is evident either in cross or surface sections. This is the *outer epiderm* (*ret*) made up of isodiametric cells with curious, often concentric, reticulations. Within this layer are *compressed cells* (p^3) through which runs the raphe in one of the narrower sides of the seed.

Endosperm (Figs. 256 and 258, *E*).—Typical *aleurone cells* form a single row. In surface view they are sharply angular. The *aleurone grains* are scarcely measurable.

Embryo (Figs. 256 and 258, *C*).—As in the endosperm the visible contents are aleurone grains and fat. In the outer layers of the cotyledons the *aleurone grains* are small but further inward they reach a maxi-

[1] Untersuchungen über die kohleähnliche Masse der Kompositen (Botanische Theil), Denkschr. math.-naturwiss. Kl. Kaiserl. Akad. Wissensch. 1911, **87**, 109.

[2] Sitzungsber. Kais. Akad. math.-naturwiss. Kl. 1907, Abt. 1, **116**, 19; also Wiesner's Festschrift. 1907, p. 145.

mum of 25 μ and average about 10 or 12 μ. They are elliptical or ovate and contain minute globoids.

CHIEF STRUCTURAL CHARACTERS.—Involucre ribbed and horned, 1 cm. Pericarp and spermoderm thin.

Involucre with jointed epidermal hairs; primary ribs with two fiber bundles. Epicarp of wavy-walled cells with round pores; hypoderm of beaker-shaped stone cells; phytomelan present; fibers longitudinal, forming continuous zone. Spermoderm with isodiametric reticulated epidermal cells. Endosperm of single aleurone layer. Embryo with aleurone grains (up to 25 μ) and fat.

RAGWEED

Ambrosia artemisiæfolia L.

Common ragweed, like giant ragweed or kinghead, is an American plant. It is one of the worst garden weeds and in sections infests grain fields. Selby [1] states that it is a universal weed in Ohio fields, following the grain crop, the seed retaining its vitality many years.

MACROSCOPIC STRUCTURE.—The plant may be described as kinghead on a smaller scale. The length of the *involucre* seldom exceeds 4 mm.

MICROSCOPIC STRUCTURE.—Although the general structure is like that of kinghead, there are certain differences in detail as follows:

Involucre.—The *sclerenchyma layer* is much reduced in thickness and there is only one *fiber bundle* in each rib and sometimes this is undeveloped.

Pericarp.—The beaker-shaped stone cells of the *hypoderm* are higher than in kinghead, reaching 50 μ or over. Within the *brown layer* of carbon-like substance the *outer fibers* of the closed fiber zone are longitudinally elongated, whereas the *inner fibers* are for the most part transversely elongated.

Spermoderm, Endosperm, and Embryo.—As in kinghead.

CHIEF STRUCTURAL CHARACTERS.—Involucre shorter (4 mm.) and thinner than in kinghead.

Involucre with not more than one fiber bundle in each rib. Pericarp stone cells higher (50 μ) than in kinghead; fibers of inner pericarp transverse.

[1] Ohio Agr. Exp. Sta. 1906, Bul. **175**, 363.

BURDOCK

Arctium Lappa L. = *Lappa officinalis* All.

Fr. Bardane. Sp. Bardana. It. Iappola. Ger. Gemeine Klette.

In addition to the type, three forms (*L. major* Gærtn., *L. minor* D.C., *L. tomentosa* Lam.), formerly considered to be species, are now regarded as varieties.

No better illustration than the burdock can be found of a plant that in certain regions is a vile weed and in others a valuable food plant. Kondo,[1] after stating that in Japan the root is one of the most valuable vegetables (see Gobo under Vegetables, Volume II), describes the physical and histological characters of six horticultural varieties. The root of the weed is gathered in occidental countries for use in medicine, the fleshy cultivated roots not being suited for this purpose.

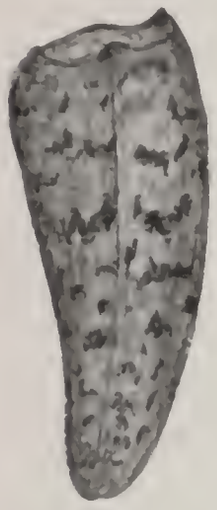


FIG. 259. Burdock.

FIG. 260. Bull Thistle.

FIG. 261. Canada Thistle

Seeds (achenes). ×5. (A.L.W.)

Fruits of the weed are here described partly because of their probable occurrence in grain and screenings and partly because of their taxonomic and histological relation to thistles which are recognized impurities.

MACROSCOPIC STRUCTURE.—The plant and *flower heads* are much the same as in the thistles, but the *involucre tips* are hooked instead of being merely pointed and the *pappus* is short and rough. Although the flower head is smaller than that of Canada thistle the *achene* (Fig. 259) is much larger than the achene of the Canada or bull thistle, being 5 to 7 mm. long and 2.5 to 3.5 mm. wide. It is further distinguished by its wrinkled surface, the short blunt teeth of the crown in which the ribs end, and, usually, the black blotches on the brown background.

MICROSCOPIC STRUCTURE.—Kondo[1] describes in detail the structure of the achene of the cultivated form and gives illustrations showing the tissues in cross section and after isolation by maceration. His important study is the first worthy of mention not only on this fruit but on the group including the thistles.

The general structure of the wild as well as the cultivated form is much like that of the thistles except that the elements are more robustly developed.

[1] Ohara Inst. landw. Forsch. Ber., 1919, **1**, 428.

Pericarp.—(1) The *epicarp* cells are 20 to 70 μ high, being highest in the depressions between the wrinkles, with outer walls 10 μ thick, (2) the *mesocarp* has bolder *fiber* elements with thicker and more conspicuously reticulated walls than those of the thistles, and (3) the *endocarp* cells, each with an oxalate *crystal*, are clearly evident in cross section.

Spermoderm.—The *outer epiderm* cells average 80 μ high and reach a maximum of over 100 μ. Kondo notes their parallelogram shape as seen in radial section or in the macerated material.

Perisperm and Endosperm.—As in Canada thistle.

Embryo.—The *aleurone grains* in the interior of the cotyledons are rounded-angular. They reach 18 μ, and on the average are over 10 μ in diameter.

Chief Structural Characters.—Achenes (up to 7 mm.) larger than those of thistles, with crown teeth and blotches.

Epicarp cells high (70 μ) with thick (10 μ) outer walls; endocarp crystals distinct. Spermoderm with parallelogram cells; embryo with aleurone grains up to 18 μ.

BULL THISTLE

Carduus lanceolatus L. = *Cnicus lanceolatus* Hoffm. = *Cirsium lanceolatum* Scop.

Fr. Chardon. Sp. Cardo silvestre. It. Cardo. Ger. Disteln.

In certain sections the common or bull thistle is more troublesome than the Canada thistle, from which it is readily distinguished by its much larger leaves, flower heads, and achenes, as well as by the greater number of flowers. Both species are natives of Europe.

MACROSCOPIC STRUCTURE.—The *achenes* (Fig. 260) are usually light gray-brown, 3 to 4 mm. long, 1 to 2 mm. wide. Other characters are as described for Canada thistle.

MICROSCOPIC STRUCTURE.—Although analogous in structure to Canada thistle the cells of the *epicarp* are higher (up to 15 μ) and have thicker outer walls (up to 7 μ) and the parallelogram cells of the spermoderm are higher (up to over 100 μ). The *aleurone grains* of the seed are not, however, noticeably larger than in Canada thistle.

Chief Structural Characters.—*Achene* 3 to 4 mm. long (smaller in Canada thistle, larger in burdock). Epicarp cells higher (15 μ) with thicker outer walls (up to 7 μ) and parallelogram cells higher (100 μ) than in Canada thistle.

CANADA THISTLE

Carduus arvensis L. = *Cnicus arvensis* Hoffm. = *Cirsium arvense* Scop.

Fr. Chardon. Sp. Cardo canadiense. It. Cardo. Ger. Disteln.

Although known as Canada thistle, the plant is of European origin. It is a perennial weed in grain field and meadow hard to eradicate because of its creeping roots.

MACROSCOPIC STRUCTURE.—The flower head, as in other plumed thistles, has a prickly *involucre*, numerous tubular *flowers*, and one-seeded achenes with plumose pappus bristles becoming detached at maturity. Characteristic of this species are the numerous flowerheads, their small size, and the small achenes. The *achenes* (Fig. 261) are of a medium brown color, 2 to 3 mm. long and 0.5 to 1 mm. wide. They are flattened or angular, obscurely ribbed, often curved, somewhat constricted near the ring-bordered apex, and tapering to the base—characters shared with the larger and lighter colored achenes of the bull thistle. The pericarp, spermoderm, and the perisperm are closely united in a leathery coat. A thin layer of endosperm immediately encloses the large embryo consisting chiefly of the two fleshy cotyledons.

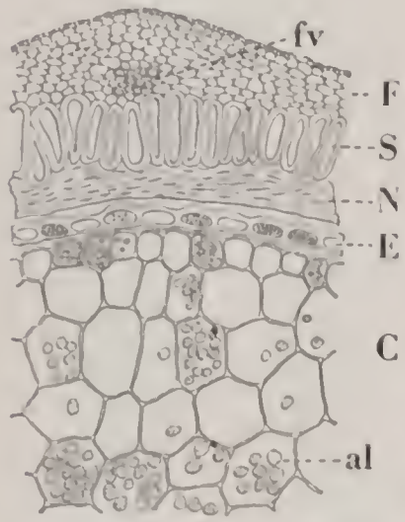


FIG. 262.—Canada Thistle. Achene in cross section. *F* pericarp: epicarp with thickened outer walls, mesocarp of thin-walled spiral-reticulated fibers, endocarp of small cells. *S* spermoderm: radially flattened parallelogram-shaped sclerenchyma cells, and compressed inner cells. *N* perisperm. *E* endosperm. *C* cotyledon with *al* aleurone grains. ×160. (A.L.W.)

MICROSCOPIC STRUCTURE.—The general structure of Canada thistle is like that of bull thistle and burdock, but the elements, notably the epicarp and the palisade cells of the spermoderm, are smaller.

Pericarp (Fig. 262, *F*).—Of the following three layers present in the earlier stages of growth the third is more or less obliterated at full maturity: (1) *epicarp* of small, longitudinally elongated cells, characterized in cross section by the thickened outer wall, (2) *mesocarp* of several rows of thin-walled, finely spiral-reticulated elongated cells or fibers, and (3) *endocarp* with crystals.

The thickness of the *epicarp* layer, as seen in cross section, varies up to 9 μ, of the outer wall up to 4.5 μ. Stained with chlorzinc iodine the outer wall is blue, the thin cuticle yellow.

Spermoderm (Fig. 262, *S*).—Only one layer with distinct cells is evident at maturity, namely, the *outer epiderm*. These cells are like those

of burdock, first noted by Kondo,[1] but are about half as high (average 35 μ, maximum 50 μ). They are radially flattened, appearing, in both cross and tangential sections, like palisade cells. When isolated by maceration they are more or less rounded diamond-shaped, or, as aptly described by Kondo, parallelogram-shaped. The walls are of quite even thickness, of a yellow color, and stain a beautiful carmine with safranin, contrasting strongly with the other tissues. Within the outer epiderm is a tissue of compressed *parenchyma* part of which, especially that about the raphe, is spermoderm.

Perisperm (*N*).—Most of the collapsed *parenchyma* consists of perisperm.

Endosperm (*E*).—A layer of *aleurone cells*, one thick, with minute *aleurone grains*, surrounds the embryo.

Embryo (*C*).—The thin-walled cells of the cotyledon contain round, irregularly rounded, or elliptical aleurone grains, usually 3 to 6 μ, reaching a maximum of 7 μ in the inner portion. Minute globoids are evident in turpentine mounts.

Chief Structural Characters.—Achenes small (3 mm.).

Epicarp cells low (9 μ), outer walls 4.5 μ; mesocarp cells small, finely reticulated; endocarp crystals small. Spermoderm with parallelogram cells up to 50 μ high (lower than in bull thistle and burdock). Phytomelan absent.

[1] Ohara Inst. landw. Forsch. Ber. 1919, **1**, 428.

PART III

FORAGE PLANTS

PART III

FORAGE PLANTS

Of the plants grown for green forage or hay, those of greatest importance belong in the grass and legume families. Members of the cactus family are the forage plants of the arid southwestern portion of the United States. Accordingly, the matter presented in this part of the volume, which aims to be suggestive of the relation of structure to composition but is obviously far from exhaustive, is grouped under the three heads: grasses, legumes, and cacti.

Plants of other families, used locally, are too numerous to mention. Among those which have been exploited are sunflower (*Helianthus annuus* L.), Jerusalem artichoke (*H. tuberosus* L.), buckwheat (*Fagopyrum esculentum* Mönch.), prickly comfrey (*Symphytum officinale* L.), Russian spurrey (*Spergula maxima*), chickling vetch (*Lathyrus sativus* L.), and black grass (*Juncus geradi* Loisel) of salt marshes.

None of the forage plants is suited for human food. Although the importance of leaf vegetables of the human dietary, particularly the salad plants, is well recognized, none of them approaches in coarseness the staple forage plants which supply domestic animals with the bulk of their food. Not only do these plants contain from 20 to 40 per cent (straw up to 50 per cent) of fiber calculated to the dry basis, but the mechanical condition of the fiber is harsh and the presence of silica in the stalks and chaff of cereals adds further to their unsuitability to the digestive system of man.

This group is as distinctly fibrous as the cereals are starchy and the oil seeds are oily and could appropriately be classed as cellulose foods. The cellulose and accompanying lignin, cutin, suberin, and other allied substances, unlike starch, oil, or even the carbohydrate in the thickened cell walls of the ivory nut, coffee bean, date stone, and persimmon, are neither reserve food for the plant nor nutrient for animals. Proteins, fat, carbohydrates, and mineral constituents make up the available food, but these need to be supplemented in many cases by concentrated feeds such as the by-products of the cereals and other starch seeds and the cakes from the oil seeds.

FORAGE GRASSES

(*Graminæ*)

THE grass family is a large one, and many of its species, fresh or dried as hay, furnish feed for stock, although in any one region only a few species or varieties are actually planted by the farmer. The subject is here treated briefly, but it should not be overlooked that the grass blade is to cattle and thus indirectly to man what the cereal grain is directly to man. A product of such immeasurable value to the race well deserves a separate monograph taking due cognizance of the hitherto untrodden field of comparative histology.

MACROSCOPIC STRUCTURE.—In diagnosis the macroscopic structure is more important than the microscopic, since grass is cut for hay when in bloom and the species is determined by botanical analysis with the aid of a dissecting lens according to the schemes in standard manuals of botany.

The culm (stalk) and leaves, which form a large part of the hay, are much alike in general structure in the several species—even in maize notwithstanding the greater size of the parts. The *culm* is cylindrical or nearly so with a series of swollen nodes from which arise alternately the leaves. The lower part of the leaf clasps the culm for a considerable distance forming a *sheath*. At the point where the blade begins is a short papery extension of the sheath known as the *ligule*. The strap-shaped *leaf blade* is much elongated and at the apex is pointed, blunt, or, as in the case of *Poa*, has a boat-shaped tip. The midrib is somewhat more pronounced than the lateral ribs which run parallel to it.

The general structure of the *flower* and the chaff elements are described in the introduction to cereals. Some of the forage grasses such as *Phleum pratense* (timothy) have heads similar to those of wheat or barley, others such as species of *Poa* (June grass, etc.) and *Agrostis* (red-top, etc.) have spreading panicles. The number of flowers in the spikelet varies from one as in *Agrostis* and *Phleum* to two or more as in *Poa*, *Festuca* (fescues), *Dactylis* (orchard grass), etc. Further details of the flower are given in manuals of botany.

MICROSCOPIC STRUCTURE.—The microscopic structure of the mature seed of forage grasses plays an important part in the examination

of grass seed designed for planting. This subject is treated in Harz' Samenkunde.[1] When cut in flower, only the chaff elements of the flowering head show in any considerable degree the characteristic structure of the mature grain. Hay of grasses is sold as such and not ground, as in the case of alfalfa, or separated after grinding into products and by-products, as in the case of cereals, hence there is no occasion for microscopic diagnosis, but as a stepping stone to further research the minute structure may prove invaluable. The histology of the fruit and perhaps the leaf may also throw light on perplexing problems of botanical classification, plant breeding, and other kinds beyond the scope of this work. Only the general structure of the stalk and leaf, with illustrations drawn from a representative species, timothy (*Phleum pratense*), is here given consideration.

Stalk (Culm).—Early histologists noted the remarkable structure of the bundle of the maize stalk. Sachs' illustration of a cross section

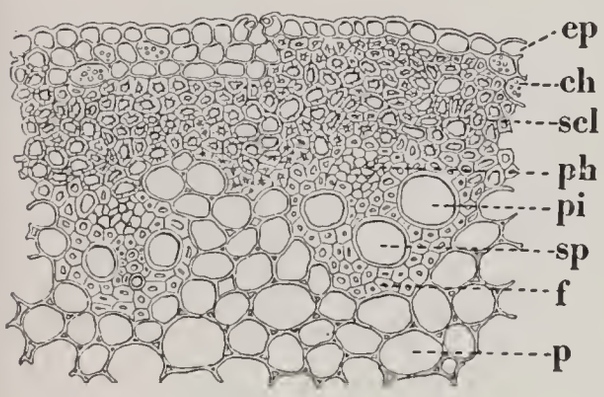


Fig. 263.

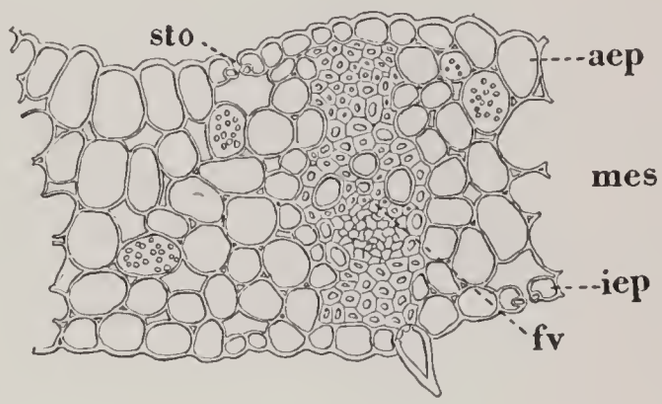


Fig. 264.

Fig. 263.—Timothy. Culm in cross section. *ep* epiderm; *ch* chlorophyl parenchyma; *scl* sclerenchyma; vascular bundle with *f* sheath, *ph* phloem, *sp* spiral vessel, and *pi* pitted vessel; *p* pith. ×160. (K.B.W.)

Fig. 264.—Timothy. Leaf in cross section: *aep* outer epiderm with *sto* stoma, *mes* mesophyl with *fv* vascular bundle, *iep* inner epiderm with hair and stoma. ×160. (K.B.W.)

which was published first in his "Lehrbuch," later in both the German and English editions of De Bary's "Vergleichende Anatomie" and Sachs' "Vorlesungen," as well as in a number of textbooks, is familiar to every student of vegetable histology. Even in imperfectly cut sections the striking appearance of the bundles and their even distribution through the pith tissues, forming as it were islands in a billowy sea of parenchyma, once seen is never forgotten.

The structure of the stalk of timothy (Fig. 263) differs little from

[1] Berlin, 1885.

that of maize except in the size of the bundles and the size of the bundle elements, notably the vessels. The tissues are (1) *epiderm* (*ep*) of longitudinally elongated, wavy-walled, pitted cells, round cells and occasional stomata, (2) *hypoderm* of several layers of thick-walled, longitudinally elongated, pitted sclerenchyma cells (*scl*) interrupted beneath the epiderm at intervals by groups of chlorophyl parenchyma (*ch*), and (3) *pith* (*p*) of large, thin-walled, pitted parenchyma with scattered fibro-vascular bundles.

The elements of the typical bundle are (1) *sheath* (*f*) of sclerenchyma cells, (2) *xylem* consisting of two large pitted vessels (*pi*), and one or more spiral or annular vessels (*sp*), arranged in the point of a V which they form with the pitted vessels, (3) *phloem* (*ph*) of sieve tubes and the

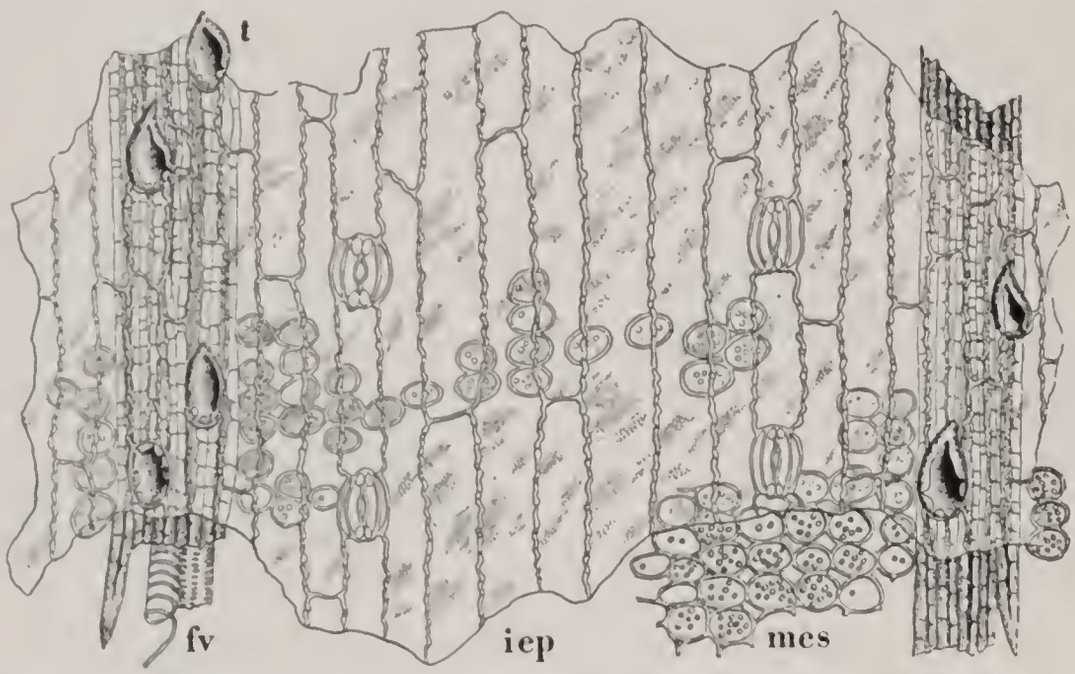


FIG. 265.—Timothy. Leaf in surface view. *iep* lower epiderm with stomata and *t* hairs; *fv* fibro-vascular bundle; *mes* mesophyl. ×160. (K.B.W.)

accompanying cambiform cells, and (4) *thin-walled cells* adjoining the vessels.

Leaf.—The plan of the timothy leaf (Figs. 264 and 265) differs from that of the stalk chiefly in that (1) it has two *epiderms* (*aep*; *iep*) each with elongated cells and numerous stomata (*sto*), also short, saw-toothed hairs on the margins and ribs, (2) the *bundles* (*fv*) are arranged in a single row and each one, corresponding to a rib, extends from one epiderm to the other, and (3) the *mesophyl* between the bundles is rich in chlorophyl grains. There is no well-developed palisade layer, the tissues under both epiderms being somewhat loose, thus permitting a free exchange of gases in the process of photosynthesis.

The *parenchyma* between the bundles contains the greater part of the available food elements.

CHEMICAL COMPOSITION.—Analyses of numerous native species are given by Richardson as an appendix to Vasey's "Agricultural Grasses and Forage Plants of the United States." [1] The summaries of analyses given in the tables on the two following pages are from Jenkins and Winton's Compilation of Analyses of American Feeding Stuffs.[2] In the first table some of the more important grasses, including maize, cured in the laboratory but calculated to the fresh materials are represented, also silage; in the second table field-cured hays, corn fodder, and straw. The wide range in composition is due in large degree to the difference in the water content, especially in the case of the green fodder, but even when that element is eliminated by calculation to the dry basis the range of protein, fat, fiber, and ash, when a considerable number of analyses is taken into account, is often as one is to three or even greater, whereas in grain and seeds it is usually no higher than one to two. Variety, season, stage of development, and care in handling are some of the causes that bring about such wide variation.

Agricultural chemical literature contains some results on the individual proteins, carbohydrates including pentosans, and other chemical constituents, for which there is here no space.

Mineral Constituents.—The composition of the ash of different species of grasses is given in Wolff's "Aschenanalysen" (1880) and in later works on agricultural chemistry; that of 32 native grasses by Richardson in an appendix to Vasey's "Agricultural Grasses and Forage Plants of the United States." [1] The following averages of analyses of meadow hay and the maize plant cut when in bloom, in percentages of the dry material, are fairly representative of the group:

Composition of Ash of Meadow Hay and Maize (Wolff)

	Total ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Meadow hay	7.06	2.07	0.42	0.49	0.27	0.14	0.56	0.27	2.50	0.41
Maize plant	6.00	2.16	0.27	0.81	0.69	0.16	0.65	0.22	0.87	0.46

Minor Mineral Constituents.—Results on these by modern methods are meager. McHargue,[3] however, obtained the following in Kentucky blue grass: iron 336, manganese 30, copper 7.5, and zinc 28 mg. per kilo, dry basis.

[1] U. S. Dept. Agr., 1889, Spec. Bul.
[2] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11**.
[3] J. Agr. Res. 1925, **30**, 193.

COMPOSITION OF FODDER GRASSES AND SILAGE

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
Green Fodder		%	%	%	%	%	%
Maize (*Zea Mays*):	126						
Min	.....	51.5	0.5	0.1	3.0	1.9	0.6
Max	.....	93.6	4.0	1.6	36.3	11.4	2.6
Aver	.....	**79.3**	**1.8**	**0.5**	**12.2**	**5.0**	**1.2**
Aver. (dry basis)	.....	....	8.8	2.6	58.9	24.1	5.6
Sorghum (*Andropogon* sp.):	11						
Min	.....	63.9	0.9	0.2	5.3	4.7	0.7
Max	.....	86.4	2.6	1.1	21.5	9.1	2.3
Aver	.....	**79.4**	**1.3**	**0.5**	**11.6**	**6.1**	**1.1**
Aver. (dry basis)	.....	.....	6.5	2.3	56.2	29.7	5.3
Rye (*Secale cereale*):	7						
Min	.....	74.7	2.3	0.2	4.9	4.7	1.3
Max	.....	84.3	3.0	0.7	12.4	14.9	2.4
Aver	.....	**76.6**	**2.6**	**0.6**	**6.8**	**11.6**	**1.8**
Aver. (dry basis)	.....	....	11.1	2.5	29.2	49.5	7.7
Oats (*Avena sativa*):	5						
Min	.....	31.3	1.5	0.4	10.8	7.1	1.5
Max	.....	78.6	6.1	3.0	39.8	16.8	4.2
Aver	.....	**62.2**	**3.4**	**1.4**	**19.3**	**11.2**	**2.5**
Aver. (dry basis)	.....	....	9.1	3.7	51.1	29.5	6.6
Timothy (*Phleum pratense*):	56						
Min	.....	47.0	1.3	0.6	10.1	5.1	1.4
Max	.....	78.7	3.8	2.0	28.6	19.4	3.2
Aver	.....	**61.6**	**3.1**	**1.2**	**20.3**	**11.8**	**2.1**
Aver. (dry basis)	.....	....	8.0	3.1	52.8	30.7	5.4
June Grass (*Poa pratensis*):	18						
Min	.....	51.7	2.4	0.8	6.5	3.8	1.6
Max	.....	82.5	7.2	1.9	26.6	14.8	4.8
Aver	.....	**65.1**	**4.1**	**1.3**	**17.6**	**9.1**	**2.8**
Aver. (dry basis)	.....	....	11.8	3.7	50.3	26.2	8.0
Red Top (*Agrostis vulgaris*):	5						
Min	.....	57.3	2.0	0.6	11.7	6.5	1.7
Max	.....	76.2	4.3	2.2	24.1	15.7	2.8
Aver	.....	**64.8**	**3.3**	**1.2**	**19.1**	**9.4**	**2.3**
Aver. (dry basis)	.....	....	9.4	3.3	53.9	26.8	6.6
Tall Oat Grass (*Arrhenatherum avenaceum*):	3						
Min	.....	62.3	1.7	0.6	13.0	9.2	1.6
Max	.....	73.5	3.3	1.5	20.7	9.7	3.0
Aver	.....	**69.5**	**2.4**	**0.9**	**15.8**	**9.4**	**2.0**
Aver. (dry basis)	.....	....	7.8	3.0	51.8	30.7	6.7
Orchard Grass (*Dactylis glomerata*):	4						
Min	.....	66.9	1.9	0.7	9.9	5.8	1.6
Max	.....	77.3	4.1	1.3	16.6	11.1	2.9
Aver	.....	**73.0**	**2.6**	**0.9**	**13.3**	**8.2**	**2.0**
Aver. (dry basis)	.....	....	9.6	3.3	49.3	30.4	7.4
Meadow Fescue (*Festuca pratensis*):	4						
Min	.....	67.6	1.8	0.7	12.5	10.2	1.6
Max	.....	73.2	2.9	1.1	15.7	11.3	2.0
Aver	.....	**69.9**	**2.4**	**0.8**	**14.3**	**10.8**	**1.8**
Aver. (dry basis)	.....	....	8.0	2.8	47.5	35.7	6.0
Silage							
Maize:	99						
Min	.....	62.4	0.7	0.2	5.1	3.0	0.3
Max	.....	87.7	3.6	2.0	24.2	10.5	3.3
Aver	.....	**79.1**	**1.7**	**0.8**	**11.1**	**6.0**	**1.4**
Aver. (dry basis)	.....	....	8.0	3.8	53.0	28.6	6.6

COMPOSITION OF HAY OF GRASSES AND STRAW

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Maize (*Zea Mays*):	35						
Min	.....	22.9	2.7	0.6	20.6	7.5	1.5
Max	.....	60.2	6.8	2.5	47.8	24.7	5.5
Aver	.....	**42.2**	**4.5**	**1.6**	**34.8**	**14.3**	**2.7**
Aver. (dry basis)	.....	....	7.8	2.8	60.1	24.7	4.6
Red Top (*Agrostis vulgaris*):	7						
Min	.....	6.8	5.9	1.4	44.8	24.0	3.8
Max	.....	11.6	10.4	3.2	50.4	31.8	7.0
Aver	.....	**8.9**	**7.9**	**1.9**	**47.5**	**28.6**	**5.2**
Aver. (dry basis)	.....	....	8.7	2.1	52.1	31.4	5.7
Orchard Grass (*Dactylis glomerata*):	11						
Min	.....	6.5	6.6	1.7	32.9	28.9	5.0
Max	.....	13.6	10.4	3.3	48.6	38.3	7.9
Aver	.....	**9.9**	**8.1**	**2.6**	41.0	**32.4**	**6.0**
Aver. (dry basis)	.....	....	9.0	2.9	45.4	36.0	9.0
Timothy (*Phleum pratense*):	68						
Min	.....	6.1	3.8	1.0	34.3	22.2	2.5
Max	.....	28.9	9.7	4.0	58.5	38.5	6.3
Aver	.....	**13.2**	**5.9**	**2.5**	**45.1**	**29.0**	**4.4**
Aver. (dry basis)	.....	....	6.8	2.9	51.7	33.5	5.1
Hungarian grass (*Setaria italica*):	12						
Min	.....	4.9	4.7	1.5	44.4	23.6	5.0
Max	.....	9.5	12.3	3.5	53.0	31.3	7.5
Aver	.....	**7.7**	**7.5**	**2.1**	49.0	**27.7**	**6.0**
Aver. (dry basis)	.....	....	8.1	2.3	53.1	30.0	6.5
Wheat (*Triticum sativum*) Straw:	7						
Min	.....	6.5	2.9	0.8	31.0	34.3	3.0
Max	.....	17.9	5.0	1.8	50.6	42.7	7.0
Aver	.....	9.6	**3.4**	**1.3**	**43.5**	**38.1**	**4.2**
Aver. (dry basis)	.....	....	3.8	1.4	48.1	42.1	4.6
Rye (*Secale cereale*) Straw:	7						
Min	.....	6.3	2.2	1.0	41.0	32.7	2.8
Max	.....	9.7	3.6	1.6	52.9	43.3	3.6
Aver	.....	**7.1**	**3.0**	**1.2**	**46.6**	**38.9**	**3.2**
Aver. (dry basis)	.....	....	3.2	1.3	50.2	41.9	3.4
Oat (*Avena sativa*) Straw:	12						
Min	.....	6.5	2.7	1.7	33.5	31.8	3.7
Max	.....	18.3	6.9	3.2	51.4	45.1	6.7
Aver	.....	**9.2**	**4.0**	**2.3**	**42.4**	**37.0**	**5.1**
Aver. (dry basis)	.....	....	4.4	2.5	46.8	40.7	5.6

FORAGE LEGUMES

(*Leguminosæ*)

ALTHOUGH a large family, only a comparatively few legumes are used as green forage and fewer still are cured for hay. Alfalfa, extensively cultivated in the arid regions of the United States, and peanut plants, cured with or without the nuts attached, are ground and bagged, thus furnishing important commercial feeds.

COMPARATIVE MACROSCOPIC STRUCTURE.—All the forage legumes have the familiar alternate, compound leaves and papilionaceous flowers developing into fruits with dehiscent pods. The stem may be stiff enough to hold the plant erect, as in soy and alfalfa, or weak, depending on tendrils to hold it upright as in the pea. The hay may or may not contain fruits in varying stages of maturity.

COMPARATIVE MICROSCOPIC STRUCTURE.—Passing over the flowers, which except for the calyx tissues that partake of leaf structure show the common floral elements, and the fruits, the tissues of greatest interest as forage belong to the leaf. The cell walls throughout are mostly thin, chlorophyl is abundant, crystals are found here and there, and hairs, both unicellular and capitate, occur on the epiderms, excepting the common pea.

The chief characters of the lower epiderm of the species here described are tabulated on the following page.

The table does not include data on bird's-foot trefoil (*Lotus corniculatus* L.—not to be confused with the water plant), sanfoin (*Onobrychis sativa* Lam. *O. vicæfolia* Scop.), and serradella (*Ornithopus sativus* Brot.), although analyses of the last two, made prior to 1892, appear in the table on the next page but one. These species were introduced into the United States during the last quarter of the nineteenth century when the cultivation of field legumes was stimulated by the discovery that they are able to utilize atmospheric nitrogen, but for various reasons they gave place to species better suited to American conditions. Repeated attempts to secure seed from seedsmen for garden tests and histological study were unsuccessful.

Seeds of garden legumes, together with tables showing their chief structural characters, are treated in Volume II under Seeds of the Pea Family, the peanut and soy bean in this volume under Oil Seeds.

MICROSCOPIC CHARACTERS OF LOWER EPIDERM OF LEAVES OF LEGUMES

	Cell walls	Unicellular hairs	Warts on hairs	Diameter of hairs†
Crimson clover (*Trifolium incarnatum*)	straight, finely beaded *	long, tapering, thick-walled	coarse, distinct	30 μ
Alsike clover (*Trifolium hybridum*)	straight	long, tapering, thick-walled	coarse, indistinct	13 μ
Peanut (*Arachis hypogæa*)	straight	long, tapering, thin-walled	none	15 μ
Alfalfa (*Medicago sativa*)	wavy	long, tapering, thick-walled	coarse, distinct	15 μ
Pea (*Pisum sativum*)	wavy, bloom	none	.....	.....
Soy bean (*Soja hispida*)	wavy	long, blunt, thin-walled	fine	25 μ
China bean (*Vigna sinensis*)	wavy	long and short, curved, thorn-like, thick-walled	none	various
Vetch (*Vicia* sp.)	wavy	long, tapering, flat, twisted, thick-walled	none	15 μ
Japan clover (*Lespedeza striata*)	wavy	long, abruptly sharp-pointed	fine	15 μ
Red clover (*Trifolium pratense*)	deeply sinuous with projections	long, tapering, thick-walled	coarse, distinct	30 μ

* Each cell with a papilla. † Average diameter midway between base and tip.

COMPARATIVE CHEMICAL COMPOSITION.—The composition of alfalfa and peanut is taken up in detail under their respective heads in this volume and of the seeds of garden legumes under Vegetables in Volume II. Below is a summary of analyses of other members of the group taken from Jenkins and Winton's Compilation of American Feeding Stuffs.[1] In the first table are analyses of the green fodder and in the second table of the cured hay.

In addition to the average composition of each product on the fresh or air-dry basis, the average on the dry basis is also given for stricter comparison.

Marked progress has been made during recent years in the study of individual members of the different groups of constituents, particularly in the case of alfalfa.

[1] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11.**

COMPOSITION OF GREEN FODDER LEGUMES

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Red clover (*Trifolium pratense*):	43						
Min	.....	47.1	1.7	0.3	3.5	1.8	0.9
Max	.....	91.8	7.1	1.8	25.8	14.7	4.0
Aver	.....	**70.8**	**4.4**	**1.1**	**13.5**	**8.1**	**2.1**
Aver. (dry basis)	.....	.....	15.3	3.9	45.8	27.8	7.2
Alsike clover (*Trifolium hybridum*):	4						
Min	.....	72.3	3.6	0.6	10.8	5.3	1.9
Max	.....	77.3	4.2	1.2	11.5	9.4	2.1
Aver	.....	**74.8**	**3.9**	**0.9**	**11.1**	**7.4**	**2.0**
Aver. (dry basis)	.....	.....	15.3	3.7	44.0	29.2	7.8
China bean (*Vigna sinensis*):	10						
Min	.....	72.8	1.5	0.2	1.8	1.7	1.2
Max	.....	93.1	3.5	0.6	12.9	15.3	2.7
Aver	.....	**83.6**	**2.4**	**0.4**	**7.1**	**4.8**	**1.7**
Aver. (dry basis)	.....	.....	14.3	2.6	43.6	29.0	10.5
Soy bean (*Soja hispida*):	6						
Min	.....	69.4	2.2	0.7	5.8	5.6	2.2
Max	.....	81.2	3.9	1.5	16.0	8.9	2.6
Aver	.....	**74.8**	**3.0**	**1.0**	**11.5**	**7.3**	**2.4**
Aver. (dry basis)	.....	.....	12.0	3.8	45.7	29.0	9.5
Spring vetch (*Vicia sativa*):	5						
Min	.....	76.4	4.0	0.5	4.4	1.5	1.5
Max	.....	87.1	4.8	0.8	11.4	4.5	2.1
Aver	.....	**83.8**	**4.4**	**0.6**	**6.6**	**2.8**	**1.8**
Aver. (dry basis)	.....	.....	28.2	5.0	39.8	16.7	11.2
Winter vetch (*Vicia villosa*):	4						
Min	.....	68.2	3.1	0.3	6.8	4.6	1.8
Max	.....	78.0	5.2	1.3	14.7	8.7	3.5
Aver	.....	**74.5**	**4.2**	**0.7**	**11.2**	**7.0**	**2.5**
Aver. (dry basis)	.....	.....	16.8	2.6	42.8	27.7	10.0
Sainfoin (*Onobrychis sativa*):	2						
Min	.....	73.2	3.6	0.6	7.9	4.9	2.1
Max	.....	77.1	4.6	1.0	15.2	5.9	3.9
Aver	.....	**75.1**	**4.1**	**0.8**	**11.5**	**5.4**	**3.0**
Aver. (dry basis)	.....	.....	16.8	3.3	45.5	22.1	12.3
Serradella (*Ornithopus sativus*):	6						
Min	.....	65.6	2.1	0.4	3.9	2.0	1.8
Max	.....	85.8	3.6	1.8	17.1	7.8	5.8
Aver	.....	**79.4**	**2.6**	**0.7**	**8.6**	**5.4**	**3.2**
Aver. (dry basis)	.....	.....	13.6	18.6	39.8	26.2	17.8

COMPOSITION OF HAY OF LEGUMES

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Red clover (*Trifolium pratense*):	38						
Min	.....	6.0	10.0	1.5	27.3	15.6	3.9
Max	.....	31.3	20.8	5.9	52.2	35.7	8.3
Aver	.....	**15.3**	**12.3**	**3.3**	**38.1**	**24.8**	**6.2**
Aver. (dry basis)	.....	....	14.5	3.9	45.2	29.1	7.3
Red clover (*Trifolium medium*):	10						
Min	.....	7.3	9.0	1.6	28.6	18.3	4.5
Max	.....	29.4	16.8	5.3	44.4	29.4	9.5
Aver	.....	**21.2**	**10.7**	**3.9**	**36.6**	**24.5**	**6.1**
Aver. (dry basis)	.....	....	13,5	4.9	43.0	31.3	7.3
Alsike clover (*Trifolium hybridum*):	9						
Min	.....	5.3	9.2	1.6	35.6	19.7	6.1
Max	.....	13.9	16.1	4.2	45.9	29.5	12.2
Aver	.....	**9.7**	**12.8**	**2.9**	**40.7**	**25.6**	**8.3**
Aver. (dry basis)	.....	....	14.2	3.2	44.9	28.4	9.3
China bean (*Vigna sinensis*):	8						
Min	.....	7.6	13.6	1.1	39.4	16.4	3.2
Max	.....	14.0	20.3	3.7	49.5	26.0	10.2
Aver	.....	**10.7**	**16.6**	**2.9**	**42.2**	**20.1**	**7.5**
Aver. (dry basis)	.....	....	18.6	3.2	47.2	22.5	8.5
Soy bean (*Soja hispida*):	2						
Min	.....	6.1	14.1	5.3	45.2	19.5	6.1
Max	.....	6.5	14.9	5.9	48.1	20.4	8.0
Aver	.....	**6.3**	**14.5**	**5.6**	**46.7**	**19.9**	**7.0**
Aver. (dry basis)	.....	....	15.5	5.9	49.6	21.3	7.5
Spring vetch (*Vicia sativa*):	3						
Min	.....	8.4	13.1	2.1	37.3	26.1	7.1
Max	.....	11.1	16.0	2.4	40.1	28.1	7.7
Aver	.....	**9.6**	**14.5**	**2.4**	**39.0**	**27.2**	**7.4**
Aver. (dry basis)	.....	....	16.0	2.6	43.2	30.0	8.2
Winter vetch (*Vicia villosa*):	1	11.6	23.1	3.0	36.6	19.7	5.8
(dry basis)	.....	....	26.2	3.4	41.5	22.3	6.6
Japan clover (*Lespedeza striata*):	2						
Min	.....	9.1	13.7	3.4	30.6	21.6	4.1
Max	.....	12.8	13.8	4.0	47.5	26.5	12.8
Aver	.....	**11.0**	**13.8**	**3.7**	**39.1**	**24.0**	**8.5**
Aver. (dry basis)	.....	....	15.4	4.1	43.8	27.0	9.5
Serradella (*Ornithopus sativus*):	3						
Min	.....	7.2	13.9	2.2	40.6	19.4	5.4
Max	.....	11.7	16.6	2.9	46.0	23.0	10.3
Aver	.....	**9.2**	**15.2**	**2.6**	**44.1**	**21.6**	**7.2**
Aver. (dry basis)	.....	....	16.8	2.8	48.5	23.8	8.0

Mineral Constituents.—The following average ash analyses from Wolff's "Aschenanalysen" (1880), calculated to the dry material, are fairly representative of the group. As compared with analyses of hay of grasses they show higher percentages of lime and lower percentages of silica.

Composition of Ash of Forage Legumes (Wolff)

	Total ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Alfalfa	7.46	1.83	0.15	3.15	0.39	0.10	0.66	0.44	0.45	0.26
Red clover	6.83	2.20	0.14	2.41	0.74	0.07	0.67	0.21	0.16	0.27
Crimson clover	6.08	1.40	0.52	1.92	0.37	0.12	0.43	0.15	0.99	0.22
Alsike clover	4.76	1.32	0.15	1.62	0.60	0.02	0.48	0.20	0.19	0.26
White clover	7.16	1.21	0.54	2.31	0.72	0.17	1.01	0.58	0.30	0.26
Pea plant	7.49	2.79	0.28	1.88	0.76	0.06	0.82	0.62	0.10	0.24
Vetch	10.05	3.39	0.68	2.74	0.64	0.10	1.28	0.34	0.59	0.37

ALFALFA

Medicago sativa (L.) Mill. = *Medica sativa* L.

Fr. Lucerne. Sp. Alfalfa. It. Medica. Ger. Luzerne.

Alfalfa is a native of western Asia. It was introduced into Greece at the time of the Persian war, 470 B.C., both its Greek and Latin names being derived from the country of origin, Media. As a forage and soiling crop it is today highly esteemed, because of its productiveness, especially in arid regions such as the southwestern states of the United States. Because of its brittleness alfalfa hay is difficult to handle, hence the now extensive industry of grinding the crop and shipping in bags as alfalfa meal. Although the aim is to cut the crop when in flower, fruits and seeds occur in commercial meal. Being perennial it often persists as a weed and the seed occurs as a contamination in wheat and other grain.

MACROSCOPIC STRUCTURE.—The *stem* is smooth and more or less woody. Fig. 266 shows the characters of the leaf (I), stipule, flower (II), pod (IV), and seed (III). The blue, yellow, green, or white *flowers* are borne in racemes and are followed by the coiled pods which are brown at maturity and contain dull, greenish brown *seeds* up to 3 mm., without accompanying caruncle or hilum cushion.

MICROSCOPIC STRUCTURE.—K. B. Winton[1] has studied the comparative histology of alfalfa and red and alsike clovers.

[1] Bot. Gaz. 1914, **57**, 53.

Stem (Fig. 267).—The tissues are (1) *epiderm* (*ep*) of somewhat elongated cells and stomata, (2) *cortex* with collenchyma at the angles, (3) *crystal cells* in a single layer, much like those of the leaf, (4) bast *fibers* (f^1) forming the wedge-shaped groups of the fibro-vascular bundles, (5) *phloem*, (6) *xylem* with porous (*ta*) and spiral (*sp*) vessels as well as wood fibers (f^2), and (7) *pith*.

Leaf (Fig. 268).—Beginning with the outer surface the tissues are (1) *lower epiderm* consisting of wavy-walled cells, stomata (*sto*), and numerous thick-walled, unicellular, crooked, warty hairs (t^1) up to over 1.5 mm. long and about 15 μ broad, with narrow lumen, and occasional multicellular, capitate hairs (t^2), (2) *mesophyl* of characterless chlorophyl cells and bundles accompanied by cells containing single

Fig. 266.

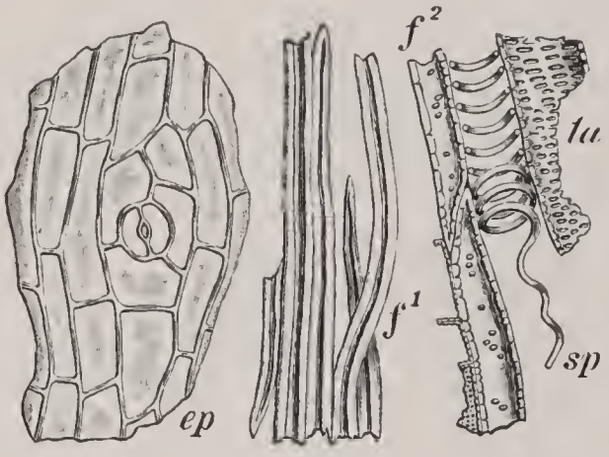


Fig. 267.

Fig. 266.—Alfalfa. I leaf. ×1. II flower. ×3. III seed. ×3. IV fruit. ×3. (K.B.W.)

Fig. 267.—Alfalfa. Elements of stem in surface view. *ep* epiderm; f^1 bast fibers; f^2 wood fibers; *sp* spiral and *ta* pitted vessels. ×160. (K.B.W.)

monoclinic crystals (*cr*) about 18 μ long, (3) *palisade cells*, half as broad as high, and (4) *upper epiderm* with strongly wavy-walled cells, stomata, and occasional hairs like those of the lower epiderm.

Flower.—The calyx tissues are very similar to those of the leaf except that on the lobes the hairs are long with broad lumens. Papillose *epidermal cells* with striate cuticle characterize the corolla of this as well as other common legumes.

Pericarp (Fig. 269).—Thin-walled unicellular and capitate *hairs* are present on the ovary, but many of these drop off during the ripening of the pod leaving thick-walled scars (*x*) on the *epicarp* (*aep*). Fibers (*f*) and crystal cells (*cr*) occur in the *mesocarp*. A characterless *endocarp* (*iep*) lines the pod.

Spermoderm (Fig. 270, *S*; Fig. 271).—The elements, which are similar to those of fenugreek, are: (1) *palisade cells* (*pal*), up to 35 μ high

and 10 μ broad with thin cuticle (*cut*) and light line (*l*) 7 μ from the rounded outer end, (2) *subepidermal cells* (*sub*), only about 6 μ high but up to 30 μ broad, with marked ribs, and (3) *parenchyma* (*p*), more or less compressed.

Fig. 271 shows the elements in surface view. The parenchyma in the outer layers (p^1) is without intercellular spaces; in the inner layers (p^2) it is a typical spongy tissue.

Endosperm (Fig. 270, *E*; Fig. 271).—This consists of a single *aleurone layer* (*ep*) and several cell layers of larger empty cells (p^3), the thin

Fig. 268.

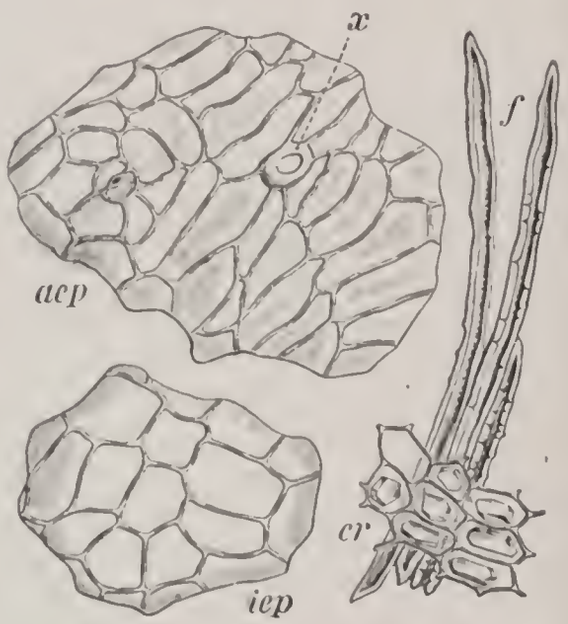


Fig. 269.

Fig. 268.—Alfalfa. Lower epiderm of leaf in surface view with t^1 warty hair, t^2 capitate hair, and *sto* stoma; *cr* crystal cells accompanying fibro-vascular bundle. ×160. (K.B.W.)

Fig. 269.—Alfalfa. Elements of pod in surface view. *aep* epicarp with *x* hair scar; *f* fibers; *cr* crystal cells; *iep* endocarp. ×160. (K.B.W.)

walls of which have mucilaginous secondary thickening which disappears in water mounts.

Embryo.—The cotyledons (Fig. 270, *C*) consist of thin-walled cells which, beneath the *inner epiderm*, are palisade-shaped. Small aleurone grains (*al*) and fat but no starch are the contents.

Chief Structural Characters.—Leaves trifoliate, flowers papilionaceous with hairy lobed calyx, pod spiral with seeds up to 3 mm.

Epidermal cells of leaves wavy-walled (in alsike clover straight); unicellular hairs distinctly warty (in alsike clover indistinctly), about 15 μ wide (in red clover about 30 μ); crystal cells in stem mesophyl and mesocarp; palisade cells of seed up to 35 μ high (in red and alsike clovers higher), rounded at top (in red clover flat); subepiderm of low (6 μ) but broad (30 μ) ribbed cells; endosperm of aleurone cells and collapsed mucilage cells; cotyledon characterless, starch-free.

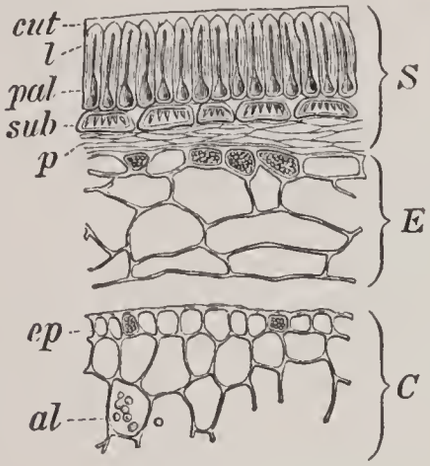


Fig. 270.

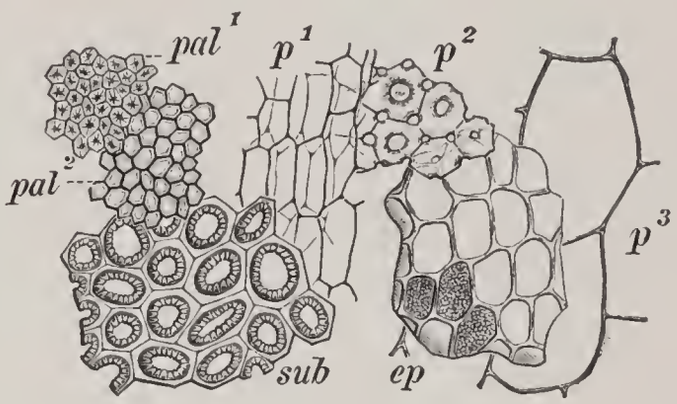


Fig. 271.

Fig. 270.—Alfalfa. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm, *p* parenchyma. *E* endosperm. *C* cotyledon: *ep* outer epiderm, mesophyl with *al* aleurone grains. ×160. (K.B.W.)

Fig. 271.—Alfalfa. Elements of seed in surface view. Spermoderm: pal^1 outer and pal^2 inner ends of palisade cells, *sub* subepiderm, p^1 outer parenchyma, p^2 spongy parenchyma. Endosperm: *ep* aleurone cells, p^3 parenchyma. × 160. (K.B.W.)

CHEMICAL COMPOSITION. Green Alfalfa.—Twenty-three analyses of green alfalfa hay made prior to 1890 at the New York, New Jersey, Pennsylvania, and Colorado Experiment Stations and the U. S. Department of Agriculture, as compiled by Jenkins and Winton,[1] contained as follows:

Composition of Green Alfalfa Hay

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	49.30	3.50	0.49	7.87	2.54	1.78
Max.	82.03	7.69	2.17	26.18	14.81	5.14
Aver.	**71.75**	**4.84**	**0.97**	**12.39**	**7.39**	**2.66**

[1] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. 11.

Alfalfa Hay.—Headden [1] has determined the composition of air-dry alfalfa hay of three cuttings and at three stages of development for each cutting, as shown below:

Composition of Alfalfa Hay (Headden)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
First cutting:						
Early bloom	7.22	15.16	1.15	30.17	36.49	9.81
Half bloom	7.92	14.46	1.26	31.67	32.80	11.89
Full bloom	6.38	15.73	1.31	31.11	34.91	10.57
Second cutting:						
Early bloom	4.43	17.68	1.71	36.01	27.47	12.70
Half bloom	9.48	17.14	1.50	36.27	24.27	11.34
Full bloom	8.56	16.41	1.78	36.24	27.11	9.91
Third cutting:						
Early bloom	8.64	16.53	1.72	36.57	24.30	12.24
Half bloom	7.43	15.52	1.52	33.92	30.55	11.07
Full bloom	8.36	15.59	1.83	33.38	30.18	10.66

A more detailed analysis by Headden [1] of the hay cut when coming into bloom yielded: water 7.21, protein 15.16, fat (ether extract) 1.15, invert sugar none, sucrose trace, dextrin trace, starch 1.11, xylan by acid 3.76, xylan by alkali 0.15, lignones 6.66, soluble in alcohol (sugar, etc., deducted) 13.87, soluble in water (dextrin, etc., deducted) 11.88, cellulose 25.59, ash 9.81, and undetermined 3.65; total 100.00 per cent.

Parts of Plant.—The loss in moisture of alfalfa hay during curing was found by Headden [2] to vary from 70.90 to 74.79 for the first cutting and from 62.91 to 74.50 per cent for the second cutting.

In addition to analyses of the hay of different cuttings and different stages of maturity Headden [1] reports analyses of the different parts of the plant including the seeds, flowers, leaves, stems, stubble, roots, bark of root, and inside portion of roots. Only the edible parts are included in the table at the top of the following page.

Jacobson and Holmes [3] found in a sample of alfalfa seed: water 6.35, protein 35.88, fat (ether extract) 11.39, nitrogen-free extract 32.43, fiber 10.52, and ash 3.43 per cent. Gasolene extraction yielded 1.92 per cent less fat than ether extraction. The determinations of the values of the oil, as given below, were made on the gasolene extract.

[1] Colorado Agr. Exp. Sta. 1897, Bul. **39**.

[2] Ibid. 1896, Bul. **35**.

[3] J. Am. Chem. Soc. 1916, **38**, 480.

Composition of Parts of Alfalfa Plant (Headden)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Seed	1	6.35	29.26	14.41	37.04	9.35	3.19
Flowers	1	4.46	21.33	2.11	42.77	19.92	9.41
Leaves:	7						
Min	.....	4.49	20.20	2.88	40.60	10.66	11.39
Max	.....	8.62	24.33	4.28	41.77	16.16	14.50
Stems	1	5.41	6.31	0.94	28.03	54.40	4.91

Analyses of the whole plant, the leaves, and the stems at different stages of maturity during two years have been made by Swanson and Latshaw [1] as shown on the following page. The maximum yield per acre of each nutrient (except fat) in 1914 was when the plant was in bud and of each nutrient without exception in 1915 was when the plant was in full bloom. These statements apply to the leaves and the stems as well as to the whole plant.

Alfalfa Feeds.—*Alfalfa meal* consisting of the ground hay, *alfalfa leaf meal* consisting of the ground leaves separated from the hay, and *alfalfa stem meal* consisting of the ground residue after removal of the leaves, are now sold in large quantities in the United States and are subject to inspection under state feed laws. The general composition of these products is well illustrated by the following summary of official analyses made under the direction of Fraps and reported by Fuller: [2]

Composition of Alfalfa Feeds

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Alfalfa meal:	46						
Min	.....	5.80	12.39	1.15	32.45	21.42	7.17
Max	.....	13.13	17.78	2.62	42.80	34.30	10.58
Aver	.....	**8.61**	**15.29**	**1.70**	**36.88**	**29.12**	**8.40**
Alfalfa leaf meal:	1	7.89	21.40	3.12	41.12	13.62	12.85
Alfalfa stem meal:	10						
Min	.....	4.45	10.66	1.12	33.86	31.18	6.06
Max	.....	9.38	13.07	1.61	40.12	38.83	7.01
Aver	.....	**7.36**	**11.56**	**1.40**	**37.78**	**35.33**	**6.57**

[1] J. Ind. Eng. Chem. 1916, **8**, 726.

[2] Texas Agr. Exp. Sta. 1929, Bul. **404**.

COMPOSITION OF ALFALFA AT DIFFERENT STAGES, SAMPLED WHEN CUT
(SWANSON AND LATSHAW)

(Results calculated to 10 per cent water content)

	In whole plant	Protein	Fat	N-f. ext.	Fiber	Ash
Year 1914	%	%	%	%	%	%
Whole plant:						
Bud	100.00	19.65	2.36	35.06	22.50	10.53
1/10 bloom	100.00	18.38	2.93	35.41	23.58	9.59
Full bloom	100.00	16.30	3.77	36.07	25.01	8.79
Seed	100.00	14.97	3.54	37.37	26.53	7.54
Leaves:						
Bud	57.57	26.17	3.27	36.01	13.64	10.78
1/10 bloom	56.40	26.16	4.06	37.40	14.06	10.52
Full bloom	51.54	22.10	5.72	39.32	13.66	9.11
Seed	43.50	21.25	5.48	39.66	14.55	8.70
Stems:						
Bud	42.43	12.57	1.23	33.92	33.54	8.78
1/10 bloom	43.61	10.63	1.33	32.97	35.12	7.97
Full bloom	48.22	9.72	1.22	35.83	36.33	7.62
Seed	56.51	10.22	1.39	34.86	36.41	7.12
Year 1915						
Whole plant:						
Bud	100.00	19.94	1.67	31.29	26.86	10.24
1/10 bloom	100.00	16.12	1.82	32.08	30.80	9.18
Full bloom	100.00	15.70	2.03	32.62	30.90	8.76
Seed	100.00	14.48	1.93	33.95	31.56	8.08
Leaves:						
Bud	47.89	27.30	3.56	32.91	15.58	10.63
1/10 bloom	41.54	24.60	3.29	33.44	18.04	10.64
Full bloom	37.65	22.70	3.60	37.78	15.91	10.01
Seed	36.58	22.21	3.11	37.91	17.28	9.49
Stems:						
Bud	52.11	13.04	0.99	30.58	36.62	8.77
1/10 bloom	58.46	10.80	0.96	38.85	40.60	6.74
Full bloom	62.35	9.83	0.97	29.15	43.37	6.38
Seed	63.42	8.91	1.02	29.79	43.21	7.07

Proteins.—During the year 1921 papers describing work on the proteins of alfalfa were published by investigators connected with three Experiment Stations, namely: Dowell and Menaul (Oklahoma), Miller (Oregon), and Osborne, Wakeman, and Leavenworth (Connecticut).

Following the same method employed in the case of pecans, peanuts, and kafir, namely, extraction with dilute sodium hydroxide solution and

precipitation with acetic acid, Dowell and Menaul [1] separated the greater part of the protein matter from alfalfa and determined the nitrogen distribution by Van Slyke's method. They consider that results by this procedure are of greater value than those on the individual proteins.

Preliminary experiments by Miller [2] showed a preponderance of nitrogen soluble in salt solution in alfalfa seed, but difficulties were experienced in an attempt to isolate a pure globulin from this source. The following amounts of nitrogen were dissolved by shaking 2 grams of the ground seed with 100 cc. of each of the solutions named and allowing to stand for 14 hours: 0.5 per cent aqueous potassium hydroxide, 4.65; 0.5 per cent alcoholic potassium hydroxide, 3.78; 5 per cent salt solution, 3.33; 5 per cent alcoholic salt solution, 1.34; alcohol, 0.71; and water, 2.01 per cent. The alcohol in each case was a mixture of equal volumes of 95 per cent alcohol and water.

The seed was then extracted on a large scale with 0.5 per cent aqueous potassium hydroxide and the protein matter precipitated from the solution by coagulation with acetic acid. After filtering it was washed first with dilute alcohol, then with an alcohol of increasing strength up to absolute, and finally dried. The preparations contained on an average carbon 53.12, hydrogen 6.95, nitrogen 15.54, and sulphur 0.70 per cent, calculated to the water- and ash-free basis. The nitrogen distribution in this material is shown below.

The same author [3] made a protein preparation from alfalfa hay using a method similar to that described above. The preparation contained nitrogen 12.9, sulphur 0.85, and ash 1.27 per cent. Repeated precipitation failed to raise the nitrogen content above 13 per cent. The dried " protein " would not dissolve in cold alkali and only with difficulty in alcoholic alkali, decomposing in the latter case.

Osborne, Wakeman, and Leavenworth [4] were able by high pressure to obtain from ground green alfalfa the greater part of the undiluted juice, containing about 10 per cent of solid matter, partly in colloidal solution. To complete the extraction they digested the residue several times with water, employing pressure to remove the liquid. In this manner over 45 per cent of the total dry matter, 42.7 per cent of the ash-free dry matter, and 43.8 per cent of the total nitrogen of the plant were removed.

On addition of 20 per cent of alcohol to the total liquid a flocculent precipitate containing over 11 per cent of nitrogen was obtained. On treatment with 75 per cent alcohol containing hydrochloric acid to remove calcium phosphate and calcium-organic compounds consisting

[1] J. Biol. Chem. 1921, **46**, 437.
[2] J. Am. Chem. Soc. 1921, **43**, 906.
[3] Ibid. 1921, **43**, 2656.
[4] J. Biol. Chem. 1921, **49**, 63.

largely of pigments similar to flavoring derivatives, the nitrogen content was raised to over 15 per cent. Further purification was effected by dissolving in dilute alkali and reprecipitation with hydrochloric acid, thus securing a substance ("colloidal protein") with over 16 per cent of nitrogen. The suspended colloidal protein combines with hydrochloric acid at room temperature without dissolving, forming a jelly on heating. With dilute alkali it gels at room temperature.

The filtrate from the flocculent precipitate, although rich in nitrogen, contained only 1 per cent of the total protein of the plant, the form being apparently that of a proteose.

The residue after removal of the water-soluble matter from the original material yielded, on successive extraction with 93 per cent alcohol, 0.3 per cent alkali in water, and 0.3 per cent alkali in alcohol, respectively, 6.4, 5.2, and 17.8 per cent of the total ash-free solids and 2, 7, and 39.3 per cent of the total nitrogen. About 60 per cent of nitrogen soluble in alcoholic alkali (nearly 24 per cent of the total nitrogen) could be precipitated by acid. The final residue contained 29.1 per cent of the ash-free solids and 5.3 per cent of the total nitrogen.

Amino Acids of Alfalfa Protein.—Jones, Gersdorff, and Moeller [1] obtained in the protein isolated by Osborne the following figures: cystine 0.93 and tryptophane 2.86 per cent.

Nitrogen Distribution in Alfalfa Proteins.—The following results by Miller [2] and by Dowell and Menaul [2] were secured by Van Slyke's method:

	Alfalfa seed protein (Miller)	Alfalfa hay protein (Miller)	Alfalfa protein (D. and M.)
	%	%	%
Humin N	4.41	6.11	7.80
Cystine N	1.01	0.91	0.85
Arginine N	21.38	13.82	11.01
Lysine N	6.11	11.04	5.26
Histidine N	5.42	3.33	6.26
Amino N of filtrate	47.87	55.98	53.53
Non-amino N of filtrate	5.32	2.38	8.48
Amide N	8.67	6.18	6.80
Total N recovered	100.19*	99.75*	99.99

* Corrected for solubility of bases.

[1] J. Biol. Chem. 1924, **62**, 183.

[2] Loc. cit.

Miller found that about 28 per cent of non-protein nitrogen was readily soluble in water regardless of the degree of fineness of the hay. The purine fraction contained 3.2 per cent of the total nitrogen.

Nitrogen Distribution in Alfalfa.—Hamilton, Nevens, and Grindley [1] determined the nitrogen distribution directly in alfalfa without attempting to separate the protein matter from other substances. Their results follow: humin nitrogen 7.36, arginine nitrogen 8.00, cystine nitrogen 0.99, histidine nitrogen 3.93, lysine nitrogen 4.43 (total basic or di-amino nitrogen 17.35), mono-amino nitrogen in filtrate from bases 38.03, non-amino nitrogen, etc., in filtrate from bases 2.51, ether-soluble nitrogen 0.55, alcohol-soluble nitrogen 1.85, non-protein nitrogen soluble in cold 1 per cent trichloracetic acid in filtrate from colloidal iron 16.69, amide nitrogen 8.17, and nitrogen lost in method of analysis 4.73; total 97.24 per cent.

Free Amino Acids, Polypeptides, Amides, and Bases.—In the "alfalfa filtrate" from the expressed alfalfa juice, after precipitation of the protein by alcohol added to 53 per cent concentration, Vickery [2] separated *asparagine* amounting to 1.8 per cent of the organic solids and containing 5.8 per cent of the nitrogen present in the filtrate but representing only one-third of the amide nitrogen as determined by Sachsse's method. Only 13.6 per cent of the total nitrogen was present in amino form, hence the amount of free amino acids was small. A small amount of *tyrosine* was isolated and the presence of a small amount of *polypeptides* indicated.

In later work Vickery [3] isolated the following amounts of bases expressed in terms of percentages of the organic solids of the concentrated filtrate: *arginine* 0.30, *lysine* 0.04, *stachydrine* 2.15, *choline* 0.14, a base containing about 50 per cent of nitrogen and yielding a picrate melting at 298° C. 0.16, and a chloride of a purine 0.03 per cent. Together these represent 13.6 per cent of the nitrogen of the filtrate.

The base combined to form a picrate was found by Vickery and Leavenworth [4] to be *adenine*. It constituted 0.012 per cent of the fresh plant and contained 2.72 per cent of the nitrogen in the filtrate.

In the "alfalfa filtrate," after removal of the precipitate formed by barium hydroxide and alcohol and by mercuric nitrate and sodium carbonate, Vickery [5] precipitated the quaternary bases with phosphotungstic acid. The nitrogen in this precipitate represented 8.48 per cent of the nitrogen in the "alfalfa filtrate," of which 6.09 per cent was contained as *stachydrine*, 0.58 per cent as *choline*, 0.13 per cent as *trimethylamine*,

[1] J. Biol. Chem. 1921, **48**, 249.
[2] Ibid. 1924, **60**, 647.
[3] Ibid. 1924, **61**, 117.
[4] Ibid. 1925, **63**, 579.
[5] Ibid. 1925, **65**, 81.

and 0.049 per cent as *betaine*. The content of these substances in the fresh plant was 0.144, 0.0115, 0.0013, and 0.00095 per cent respectively.

Vickery and Vinson,[1] in the lead subacetate precipitate from the "alfalfa filtrate" after decomposition with hydrogen sulphide and acid hydrolysis, found *adenine*, *aspartic acid*, *tyrosine*, *arginine*, *lysine*, and *stachydrine*.

Vickery,[2] operating with the "alfalfa filtrate" from about 24 kilos of the fresh plant, obtained in the mono-amino acid fraction the following results expressed in percentages of the nitrogen in the total nitrogen of the plant and of the actual substances in the fresh plant respectively: *alanine* 0.082 and 0.0049, *valine* 0.155 and 0.012, *leucine* 0.095 and 0.0086, *serine* 0.144 and 0.010, *aspartic acid* 0.294 and 0.026, *asparagine* 1.52 and 0.075, *tyrosine* 0.004 and 0.0005, and *phenylalanine* 0.032 and 0.0034 per cent. He notes that at least 55 per cent of the fraction is accounted for as asparagine and that the aspartic acid found after hydrolysis indicates the presence of a still larger amount. Serine and alanine had not previously been reported as occurring in plant juices.

Saponin.—In addition to the two ketones, Jacobson [3] isolated from the alcohol extract a saponin, $C_{27}H_{37}NO_{16}$, which unlike other saponins does not hemolyze blood. Like solanin it is nitrogenous, thus forming a connecting link between other saponins, which are non-nitrogenous, and the alkaloids. It hydrolyzes to a sapogenin, $C_{18}H_{18}NO_{10}$, also yielding a glucose derivative. Although toxic to fish, doubtless because it prevents access of air to water, it does not appear to injure higher animals when administered *per os*, but when injected subcutaneously it causes severe local irritation and death.

Fat.—The *Physical and Chemical Values* of alfalfa seed oil obtained by gasolene extraction, as determined by Jacobson and Holmes,[4] are as follows: specific gravity at 15° C. (recalculated) 0.9175, refractive index at 25° C. (recalculated) 1.4755, saponification number 172.3, iodine number 154.2, Reichert-Meissl number 0.40, insoluble fatty acids 92.5 per cent (saponification number 189.9, iodine number 169.5, neutralization value 191.5, mean molecular weight 293, and solid bromide by Hehner-Mitchel test 17 per cent), acetyl number 19.8, acid number 2.85, unsaponifiable matter 4.40 per cent, glycerol 1.97 per cent, and saponification number of acetylated oil 192.2.

Composition of Alfalfa Seed Oil.—The authors last named found liquid acids 90.4 per cent and solid acids 9.6 per cent, containing as follows:

[1] J. Biol. Chem. 1925, **65**, 91.
[2] Ibid. 1925, **65**, 657.
[3] J. Am. Chem. Soc. 1919, **41**, 640.
[4] Loc. cit.

Liquid acids	%	Solid acids	
Oleic	3.3	Carnaubic	present
Linoleic	73.2	Daturic	present
Linolenic	23.5	Behenic	present (?)

Carbohydrates.—Determinations of the individual carbohydrates by Headden appear in the general analysis above.

Widtsoe and Stewart [1] studied the carbohydrates, following Stone's scheme; the determination of starch by the diastase method, however, gave discordant results, apparently owing to active unorganized ferments.

Phosphorus-Organic Compounds. *Nucleic Acid (Nuclein).*—Widtsoe and Stewart,[1] in a comparison of the nuclein of leguminous and timothy hays and common cereals, found in the leaves and stalks of the first crop of alfalfa (old) 6.88 and 2.32 per cent and in the leaves and stalks of the second crop (young) 6.78 and 2.93 per cent respectively. They conclude from these and other results that " the percentages of nuclein in the leaves and the stalks . . . are not affected by the age of the plant, by the season, or by the place of cutting."

Organic Acids.—Euler and Bolin [2] found in alfalfa leaves *mesoxalic, glycolic, malic,* and *citric acids* in studying the oxidizing action of the enzyme " medicago-laccase."

Turner and Hartman,[3] studying the non-volatile acids, identified *citric, malic,* and *malonic acids* in the proportion of 12 : 8 : 3.

Ketones.—From the alcohol extract of alfalfa hay cut when in early bloom Jacobson,[4] by extraction with ether and treatment with nitric acid, isolated small amounts of two ketones: *myristone,* $(C_{13}H_{27})_2CO$, (melting point 74 to 75° C.) and *alfalfone,* $C_{21}H_{42}O$, (melting point 88.5 to 88.8° C.).

Coloring Matter.—Jacobson [5] found in dried alfalfa hay 0.68 per cent of chlorophyl and 0.28 per cent of yellow coloring matter. He notes that the chlorophyl is similar to that of nettle leaves. His preparation consisted of 66 per cent of *neochlorophyl* and 34 per cent of *allochlorophyl.* Only when the concentration is five times that adapted for photography does the yellow coloring matter modify the absorption spectrum of the chlorophyl, introducing changes in two parts of the ultraviolet section.

[1] Utah Agr. Exp. Sta. 1898, Bul. **58.**
[2] Z. physiol. Chem. 1909, **41,** 1.
[3] J. Am. Chem. Soc. 1925, **47,** 2044.
[4] Ibid. 1911, **33,** 2048; 1912, **34,** 300.
[5] Ibid. 1912, **34,** 1263.

Enzymes.—Alfalfa seeds have been shown by Jacobson [1] to contain starch- and amygdalin-hydrolyzing enzymes corresponding to *amylase* and *emulsin* respectively, also a renin-like enzyme (*coagulase*) that coagulates milk, one that precipitates purpurogallin from a solution of pyrogallol similar to *peroxidase*, and a peptolytic protease, classified as a vegetable *erepsin*, that acts on casein and Witte peptone. Invertase and a water-soluble lipase appear to be absent.

The above author and his co-worker Holmes in a later paper [2] record the presence in the green plant of all the enzymes found in the seed and in addition *lipase*, *invertase*, and *pectinase*. The emulsin and pectinase occur in considerable amount; the lipase, amylase, and invertase in small amount. The diastatic power of the water extract of the dried plant was about 20.

Shuey [3] reviews the literature on the *diastase* of green plants and notes the high activity of alfalfa, especially of the stems. The diastatic action is greatest in the young plant, in the morning, and during the warm season. Drying in a current of air with gradual increase in heat increases the activity and obviates losses sustained in field drying more than offsetting the increased cost.

According to Bourquelot and Hérissey,[4] a soluble ferment, *seminase*, is secreted by the embryo during fermentation, which hydrolyzes cell-wall carbohydrates to mannose and galactose.

Analyses of Alfalfa Ash * (Headden)

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	Mn_3O_4	P_2O_5	SO_3	Cl	SiO_2	CO_2	Sand
	%	%	%	%	%	%	%	%	%	%	%	%	%
First cutting:													
Not in bloom †	30.03	1.31	23.79	3.51	0.41	0.16	0.14	4.83	4.70	6.19	1.17	24.04	0.93
Half bloom	29.89	1.65	24.88	3.83	0.34	0.19	0.12	4.71	5.07	3.36	1.07	25.36	0.66
Full bloom †	26.31	0.90	26.75	3.80	0.18	0.09	0.11	4.64	4.52	7.26	1.35	24.47	1.10
Full seed †	25.98	2.94	22.02	5.21	0.40	0.24	0.21	4.93	4.93	6.27	1.29	25.14	1.95
Second cutting:													
Early bloom	25.38	1.86	25.97	3.37	0.30	0.05	0.19	3.94	6.11	7.76	0.78	24.77	0.98
Half bloom	26.87	1.76	25.61	3.68	0.25	0.10	0.15	4.63	7.07	7.92	0.58	22.61	0.91
Full bloom ‡	22.00	1.03	28.87	4.35	0.15	0.27	0.12	3.58	5.12	7.30	1.30	24.23	1.63
Third cutting:													
Hay †	28.30	3.47	23.01	3.64	0.30	0.14	0.14	3.81	4.51	6.24	0.64	26.21	0.91
Plant parts:													
Seed	35.21	1.55	5.38	9.54	0.49	0.09	0.21	38.86	1.37	0.77	0.64	4.54	1.47
Flowers	25.59	4.02	16.95	3.95	1.01	1.18	0.20	7.70	6.26	4.88	3.16	...	9.19
Leaves ‡	12.47	2.98	33.44	4.68	0.43	0.25	0.18	3.57	9.96	5.70	1.07	24.82	1.46
Stems §	32.34	4.65	15.54	4.77	0.46	0.38	0.15	5.15	2.49	7.56	1.44	24.11	1.24

* Strontia present in all the samples but lithia not detected. Carbon varied from a trace to 0.29 per cent.

† Average of 2 samples. ‡ Average of 4 samples. § Average of 3 samples.

[1] J. Am. Chem. Soc. 1912, **34**, 1730.

[2] Ibid. 1914, **36**, 2170.

[3] J. Ind. Eng. Chem. 1914, **6**, 910.

[4] Compt. rend. 1900, **130**, 731.

Mineral Constituents.—Headden [1] gives exceptionally complete ash analyses of two cuttings of alfalfa at different stages of development, the hay (third cutting), and the separate parts of the plant, from which the figures in the foregoing table are derived.

Minor Mineral Constituents. *Iron.*—Foliage 168, seeds 168 mg. per kilo, dry basis (McHargue).[2]

Manganese.—Seed 16 mg. per kilo, dry basis (Wester).[3] Hay, 15 samples, 16 to to 29, av. 23; plants, 2 samples, stems 13 and 11, leaves 76 and 45, blooms 42 and 27, and seeds 11 and 6 mg. per kilo, dry basis (Jones and Bullis).[4] Foliage 40, seeds 15 mg. per kilo, dry basis (McHargue).[2]

Copper.—Foliage 8.5, seeds 15 mg. per kilo, dry basis (McHargue).[2]

Zinc.—Foliage 112, seeds 80 mg. per kilo, dry basis (McHargue).[2]

RED CLOVER

Trifolium pratense L.

Fr. Grand trèfle. Sp. Trébol rojo. It. Trifoglio rosso. Ger. Rotklee.

A native of Europe, eastern Asia, and north Africa, red clover is a common fodder and soiling plant in the Western Hemisphere and, escaped, grows spontaneously in many regions.

MACROSCOPIC STRUCTURE.—Unlike that of alfalfa the ascending *stem* is pubescent. Each of the *leaflets* of the trifoliate leaves is broadly oval or obovate, often notched at the end, on the upper side smooth and marked with an irregular whitish spot, on the lower side somewhat pubescent. The rose-red *flower* heads are sessile, surrounded by the upper leaves. The pubescent calyx is smooth except for a beaded ring in the throat and has five bristle-like teeth nearly equaling the tubular papilionaceous corolla which withers after flowering.

Unlike alfalfa the *pod* is straight, flattened, oval, one-seeded, thin, membranous below, hard and cap-like at the top. Compared with those of alfalfa the *seeds* are smaller (about 2 mm.). They are flattened kidney-shaped or rounded triangular with one side concave and vary from light straw color to purple, with or without variegation.

MICROSCOPIC STRUCTURE. Stem and Petiole.—The *epiderm* consists of cells with straight and often beaded walls and striated cuticle, stomata, and, as on the lower surface of the leaf, two forms of hairs, the unicellular form being borne on protuberances over an air space. Below the epiderm the tissues are like those of the stem of alfalfa.

[1] Colorado Agr. Exp. Sta. 1896, Bul. **35**.
[2] J. Am. Soc. Agron. 1925, **17**, 368.
[3] Biochem. Z. 1921, **118**, 158.
[4] J. Ind. Eng. Chem. 1921, **13**, 524.

Leaf.—The cells of the *lower epiderm* (Fig. 272) are mostly sharply sinuous, often with projections at the bends. Similar projections or horns occur on the stomata. As in alfalfa two forms of *hairs* are present—warty unicellular and multicellular capitate but the former are longer, up to 2 mm., broader, about 30 μ, have more pronounced warts, and arise from the top of protuberances in the middle of a rosette of elongated straight-walled cells. Beneath this protuberance is a large air cavity. The *upper epiderm* consists of isodiametric cells with slightly wavy walls and stomata, hairs being absent.

Flower.—The structure of the calyx is much like that of the leaf, the bristle-like teeth, however, are papillous and end in a tuft of stiff unicellular hairs. The corolla has the usual papillose and striate *epiderm*.

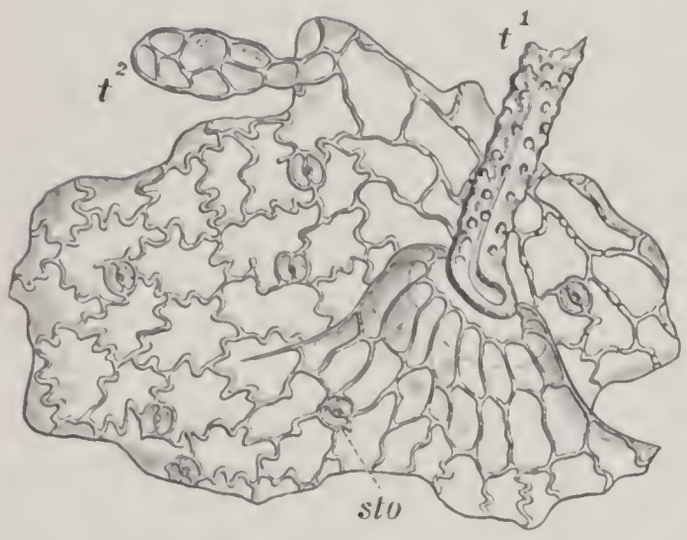


Fig. 272.—Red Clover. Lower epiderm of leaf in surface view with t^1 base of warty hair arising from swelling of the epiderm, t^2 capitate hair, and *sto* stoma. ×160. (K.B.W.)

Pericarp.—Sinuous-walled cells and stomata make up the *epicarp*. Toward the tip the cell walls abruptly change from thin to greatly thickened and sclerenchymatized with numerous pores. Scattered *crystal cells* are the only noteworthy elements of the *mesocarp*.

Spermoderm, Endosperm, and **Embryo** have the same general structure as in alfalfa except that the *palisade cells* are higher (up to 45 μ, over the radicle up to 55 μ) and broader (up to 15 μ) with flattened outer ends, and the *subepidermal cells* are somewhat higher (up to 15 μ) but narrower (up to 27 μ), and a small quantity of minute starch grains occurs in the cotyledons.

Chief Structural Characters.—Stem pubescent; leaves trifoliate; leaflets broad, notched, with light spot; flowers rose-red in sessile heads; calyx with bristle-like teeth nearly equaling tubular papilionaceous corolla; pod straight, flattened oval, one-seeded; seed 2 mm., kidney-shaped or rounded triangular, dull, yellow to purple, uniform or spotted.

Cells of lower epiderm of leaf deeply sinuous with projections; unicellular hairs distinctly warty (in alsike clover indistinctly), about 30 μ wide (in alfalfa and alsike clover about 15 μ); palisade cells of spermoderm about 45 μ high and 15 μ broad (lower and narrower in alfalfa), flattened at outer end (in alfalfa and alsike clover rounded). Cotyledons with small quantity of minute starch grains. Other characters as in alfalfa.

CHEMICAL COMPOSITION.—See tables under Forage Legumes.

Nitrogen Distribution in Red Clover Hay.—The following results by Van Slyke's method are those reported by Hamilton, Uyei, Baker, and Grindley:[1] humin nitrogen 13.09, arginine nitrogen 6.86, cystine nitrogen 0.87, histidine nitrogen 5.05, lysine nitrogen 2.62, mono-amino nitrogen in filtrate from bases 39.82, proline, oxyproline, tryptophane, and non-amino nitrogen in filtrate from bases 3.28, ether-soluble nitrogen 0.62, alcohol-soluble nitrogen 1.57, non-protein nitrogen soluble in cold 1 per cent trichloracetic acid in filtrate from colloidal iron 11.29, amide nitrogen 7.35, and nitrogen lost in method of analysis 6.87, total 99.29 per cent.

CRIMSON CLOVER

Trifolium incarnatum L.

Fr. Farouche. It. Trifoglio incarnato. Ger. Incarnatklee.

Southern Europe claims this clover as a native, and it is there that it is most grown. In the United States it is coming into prominence. Although an annual, if sowed late, it lives over Winter and blooms the next year.

MACROSCOPIC STRUCTURE.—*Stems, petioles, leaves, stipules,* and *calyx* bear numerous hairs. The *leaflets* are ovate, broad, denticulate, often notched at end, and without a whitish spot. Characteristic of the *flower* head is the dense mass of crimson flowers in a spike up to over 7 cm. long. From red and alsike clover and alfalfa the seed (up to over 2.5 mm.) is distinguished by its nearly perfect ovoid form and uniformly light brown lustrous surface.

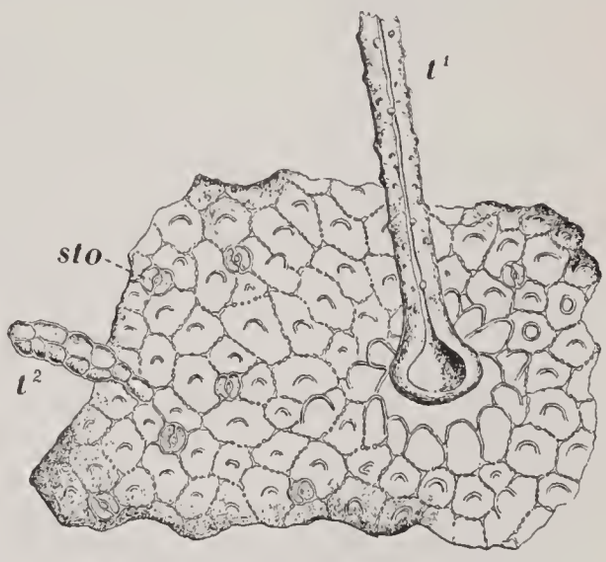


FIG. 273.—Crimson Clover. Lower epiderm of leaf in surface view with t^1 base of warty hair, t^2 capitate hair, and *sto* stoma. ×160. (K.B.W.)

MICROSCOPIC STRUCTURE.—**Stems** and **petioles** have longitudinally elongated *epidermal cells,* stomata, and two kinds of hairs as on the leaf. Numerous groups of small cells with single monoclinic crystals occur in the *pith* of the stem.

Leaf (Fig. 273).—Both *epiderms* consist of cells with straight, or nearly straight, finely but distinctly beaded walls, stomata, and unicellular (t^1) and capitate (t^2) hairs. Highly characteristic of the cells are the slender papillæ, one of which arises abruptly from the center of each cell. The

[1] J. Am. Chem. Soc. 1923, **45**, 815.

unicellular hairs (most numerous on lower epiderm) range up to 1.5 mm. long and about 30 μ wide, with thick walls, usually distinct warts, and very narrow lumen. Often they occur on slight protuberances of the epiderm.

Flower.—Structurally the calyx is similar to the leaf. Red coloring matter in solution is conspicuous in the fresh flower but turns brown on wilting.

Spermoderm.—The *palisade cells* are about 45 μ in height and 15 μ in breadth, with light line 8 μ from the flattened outer end; the subepidermal cells are about 16 μ high and 40 μ broad.

Endosperm and **Embryo** as in other clovers.

CHIEF STRUCTURAL CHARACTERS.—Stem, leaves, stipules, and calyx pubescent; leaflet broadly ovate, denticulate, without spot; flower crimson; seed up to over 2.5 mm., regularly ovate, lustrous.

Epidermal cells of leaves straight-walled, beaded, with characteristic central papillæ; unicellular hairs mostly distinctly warty, about 30 μ broad as in red clover (narrower in alsike clover and alfalfa); palisade cells of spermoderm about 45 μ high with flat outer end as in red clover.

CHEMICAL COMPOSITION.—See table under Forage Legumes.

ALSIKE CLOVER

Trifolium hybridum L.

Fr. Trèfle hybride. Sp. Trébol sueco. It. Trifoglio ibrido. Ger. Bastardklee.

The plant is indigenous to Europe but is commonly cultivated in America for forage. It is closely related to white clover (*T. repens* L.) but differs in being erect and having pinkish flowers. White clover because of its low creeping habits is not suited to harvesting.

MACROSCOPIC STRUCTURE.—Although it is described as smooth, hairs are evident under a lens on both *stem* and under surface of the leaflets. The *leaflets* of the trifoliate leaves are broad, notched on the end, and finely toothed. Numerous pedicellate *flowers* form a loose round head on a long peduncle. The five-cleft calyx is much shorter than the tubular corolla. The *pod* is straight, two- to four-seeded, the dull *seed* being green-brown and reaching 1.5 mm. in length or smaller than those of alfalfa and red clover.

MICROSCOPIC STRUCTURE. Stem and Petiole.—Practically as in red clover.

Leaf (Fig. 274).—The *lower epiderm* consists of straight-walled isodiametric cells, stomata, and occasional hairs, some (t^1) unicellular, indis-

tinctly warty, up to 800 μ long and about 15 μ wide, others (t^2) capitate. Single monoclinic crystals, 15 μ long, accompanying the fibro-vascular bundles, occur in the *mesophyl*. The *upper epiderm* is similar to the lower except for the absence of hairs.

Flower.—The calyx, while similar to the leaf in structure, has *epidermal cells* with sinuous walls. Sinuous-walled cells also make up the *epiderms* of the corolla, papillæ being present at the tip.

Pericarp.—The *epicarp* is composed of transversely elongated, somewhat sinuous-walled cells, stomata, and, especially at the margins, capitate hairs. Crystal cells occur singly or in groups in the *mesocarp*. Elongated thin-walled cells form the *endocarp*.

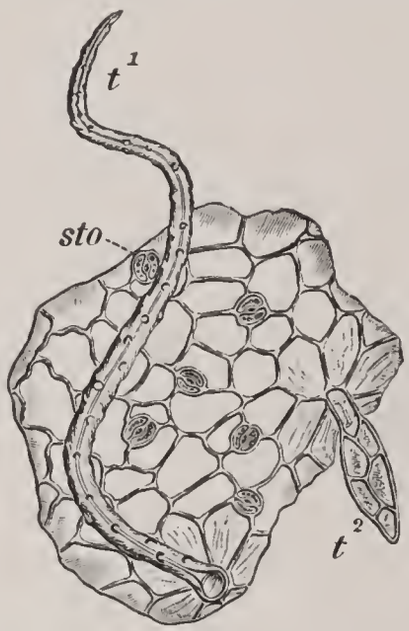


Fig. 274.—Alsike Clover. Lower epiderm of leaf in surface view with t^1 warty hair, t^2 capitate hair, and *sto* stoma. ×160. (K.B.W.)

Spermoderm.—Distinction from alfalfa and red clover lies in the palisade cells which vary up to 50 μ in height and 13 μ broad, with a light line 7 μ from the rounded outer end.

Endosperm and **Embryo** as in alfalfa except that a small quantity of minute starch grains occurs in the cotyledons.

Chief Structural Characters.—Stem nearly smooth; leaves trifoliate with broad notched leaflets; calyx five-parted, shorter than pink corolla; pod straight, two- to four-seeded; seeds green-brown, up to 1.5 mm.

Epidermal cells of leaves straight-walled (in alfalfa and red clover sinuous); unicellular hairs of lower epiderm of leaf indistinctly warty (in alfalfa distinctly), about 15 μ in diameter (in red clover about 30 μ); palisade cells of spermoderm up to 50 μ high (in alfalfa lower), rounded at outer end (in red clover flattened); cotyledons with small quantity of minute starch grains. Other characters as in alfalfa.

CHEMICAL COMPOSITION.—See tables under Forage Legumes.

PEANUT

Arachis hypogæa L.

Fr. Arachide. Sp. Cacahuate. It. Arachide. Ger. Erdnuss.

The history of the plant, also the structure of the pod and seed, are treated in this volume under Oil Seeds.

Peanut hay consists of varying proportions of stalks, leaves, blossoms, and immature pods which have not yet been forced under ground or else mature pods.

MACROSCOPIC STRUCTURE.—The somewhat angular *stem* bears soft silky hairs. Hairs are more conspicuous on the long petioles, particularly those of the younger leaves. The *stipules* are margined below and united with the base of the pedicel, often for a centimeter or more; above they are long (up to 3 cm. or more), narrow, tapering gradually to a point. The *leaves* are abruptly pinnate with two pairs of pointed, rigid, elliptical or obovate leaflets which are smooth except for occasional hairs, particularly on the margins and prominent midrib. At the tip a short bristle is evident under a lens. From the midrib parallel primary veins run to the margins, joining there a nerve forming a border about the leaf.

Of special interest are the *flower* and the *fruit*. The former is yellow or orange, small, about 1 cm. long not including the remarkable narrow, almost thread-like calyx tube which is twice that length. In external appearance the calyx tube strongly resembles a peduncle but when slit lengthwise and examined under a lens it is seen to contain the style and stamens. Above the tube the calyx is two-lipped, the lower consisting of a narrow lobe, the upper of a broad four-toothed lobe. The standard is broad and, although small, conspicuous because of its bright color; the wings are narrow and the keel bent inward at nearly a right angle. After all the flower but the minute ovary, situated at the base of the calyx tube, falls away, the stem (stipe) appears and rapidly lengthens, pushing the growing pod beneath the earth where it ripens.

MICROSCOPIC STRUCTURE. Stem.—Cross sections of the stem show: (1) *epiderm* of elongated cells and stomata, also groups of crystal cells and hairs such as occur on the lower epiderm of the leaves, (2) *collenchyma*, several cells thick, (3) *endoderm*, or starch sheath, occasionally interrupted by crystal cells in longitudinal rows, (4) *bast fiber* groups of the fibro-vascular bundles, forming an interrupted zone, (5) *phloem* of the usual type, (6) *cambium* (indistinct), (7) *xylem* with vessels as in other legumes, and (8) *pith* with starch grains up to 10 μ, grouped in aggregates in the outer layers.

The bundles are close together and the medullary rays are indistinct.

The **Petiole** differs in structure from the stem in that (1) *collenchyma* occurs only on the ridges forming the groove, (2) in other parts large cells, like those below the lower epiderm of the leaf, form the *subepiderm*, (3) *chlorophyl parenchyma* forms the next layer, two or three cells thick, (4) *bundles* are widely separated, and (5) central *pith* is normally without starch.

Leaf.—The *lower epiderm*, as seen in surface view, consists of irregular, thin-walled cells, long pointed hairs, about 15 μ broad, with two or three

foot cells and lumen usually broader than the walls, stomata, and here and there along the nerves small groups of thick-walled cells each completely filled by a coffin-shaped oxalate crystal. In the upper epiderm the crystal cells instead of following along the nerves occur in scattered small groups.

Cross sections show that beneath the upper epiderm the *mesophyl* consists of typical palisade cells containing chlorophyl, whereas beneath the lower epiderm the mesophyl cells are large, round and free from chlorophyl; also that rows of small chlorophyl-free cells run from the crystal cells of the upper epiderm to the nerve bundles.

A bast fiber strand runs about the margin of the leaf.

Stipules.—The blade is parallel veined, the *epiderm* cells are more elongated, and the hairs are commonly thinner-walled than on the leaves.

Flower.—The structure is of the usual leguminous type. Hairs occur on the calyx tube and tips of the lobes. Chromatophores give the corolla its yellow or orange color. The pollen grains are ovate up to 43 μ in diameter.

Fruit.—See Peanut in this volume under Oil Seeds.

Chief Structural Characters.—Leaves with two pairs of leaflets; flowers yellow or orange with very long, slender calyx tube and stipe which elongates rapidly and pushes the growing pod beneath the ground.

Epidermal cells of leaf with thin, straight or only slightly wavy walls, scattered crystal cells, and on the lower epiderm long, pointed hairs, about 15 μ broad, with lumen usually broader than walls (not thick-walled and warty as in alfalfa).

CHEMICAL COMPOSITION.—Below are summarized analyses by Fraps [1] of three varieties of peanut hay: (1) mowed tops, (2) pulled

Composition of Peanut Hay (Fraps)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Mowed	3	10.00	11.09	5.09	42.11	21.94	9.77
Without nuts	10	9.50	9.55	3.08	45.33	24.30	8.24
With nuts	4	8.19	13.22	13.12	34.95	23.75	6.77
Commercial:	5						
Min	.....	8.49	9.54	2.44	35.25	20.23	8.40
Max	.....	10.18	10.28	6.61	48.60	28.37	11.80
Aver	.....	**9.21**	**9.89**	**4.35**	**42.67**	**23.77**	**10.09**

[1] Texas Agr. Exp. Sta. 1917, Bul. **222**.

vines with nuts attached, and (3) pulled vines with nuts threshed off after curing; also of commercial hay from the Texas market.

Mineral Constituents.—Brown [1] obtained 15.71 per cent of ash in peanut hay (stems and leaves) and the following percentages of constituents in the ash:

	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2
	%	%	%	%	%	%	%
Leaves	15.00	7.26	50.77	10.89	4.85	3.57	5.60
Stems	19.23	7.52	25.80	19.67	5.34	7.42	9.93

SOY BEAN

Glycine Soja Sieb. et Zucc. = *G. hispida* Maxim. = *Soja hispida* Moench.

Fr. Soja. It. Soia. Ger. Sojabohne.

The structure of the seed is described in this volume under Oil Seeds; only the plant and the flowers are here considered.

MACROSCOPIC STRUCTURE.—Numerous hairs clothe the plant throughout. The *stem*, *petioles*, and *petiolules* are angled and ribbed. Often the petioles reach or exceed 15 cm. or two to three times the length of the internodes of the stem. The petiolule of the central leaflet is several centimeters long, whereas those of the side leaflets and the petioles of the two lowest simple leaves of the stem are only 1 to 2 cm. long. On all these hairs are especially numerous and reach 2 mm. or more in length.

The pointed *leaflets*, of which, as in the common bean, there are three to the leaf (excepting the lower pair), often exceed 10 cm. in length and are about two-thirds as broad. At the base they vary from obtuse to acute. The side leaflets are unsymmetrical, the midrib being often two or three times nearer one side than the other. Hairs are numerous on the under side, especially on the nerves; on the upper side they are fewer and more appressed but noticeable under a lens.

The *stipules* are broad at the base, taper-pointed, and range up to 7 mm. in length; the *stipels* are smaller.

The *flower* is small, white or purple. Of the five green, narrow, hairy calyx lobes the two upper are partly grown together. The corolla scarcely exceeds the calyx. The wings are narrow, adherent to the short

[1] Tennesee Agr. Exp. Sta. 1891, Bul. 4, II, 55.

blunt keel. The style is beardless (distinction from China bean and hyacinth bean).

MICROSCOPIC STRUCTURE. Stem, Petiole, and Petiolule.—Long before the flowers develop, these, especially the stem, are hard and woody, made up of the following tissues: (1) *epiderm* of elongated, parallel-walled cells, stomata, and long, blunt, warty hairs and short, capitate hairs, (2) *collenchyma* forming a continuous layer, (3) *cortex parenchyma*, containing chlorophyl grains, forming a thin layer, (4) *endoderm* (starch sheath), (5) *crystal cells* forming an interrupted layer, (6) *bast fibers* in groups, (7) *phloem*, with scattered crystal cells, (8) *xylem* with spiral, reticulated, and pitted vessels and wood parenchyma, and (9) *pith* of large cells forming a central column (not hollow) and containing simple and aggregate starch granules.

The finely *warty hairs*, about 25 μ broad, are unicellular except for a short foot cell. The heads of the *capitate hairs* are multicellular by transverse partitions.

Layers 6 to 8 inclusive are strongly developed and continuous about the stem except for the narrow, mostly one-cell-wide, pitted medullary rays.

The *starch granules* in the middle of the pith are simple, up to 15 μ, but one or more facets show that they are detached members of aggregates; those in the outer pith cells are remarkable aggregates with the individual grains forming swellings so that the whole resembles a blackberry.

Leaf.—Both *epiderms* are made up of wavy-walled cells, stomata, and hairs like those on the stem. On the lower epiderm the cell walls are more wavy and the stomata more numerous than on the upper. Crystal cells are not noticeable over the bundles but are scattered through the phloem.

Stipule.—The stipules differ from the leaf chiefly in having less wavy walls in the epiderms and a well-defined crystal layer over the vascular bundles.

Flower.—The *calyx* is covered with long, thin-walled, blunt-tipped, very warty hairs which are unicellular except for a short basal cell. Similar hairs cover the young fruit. The *corolla* is characterless except for typical epidermal papillæ. The pollen grains are round, smooth, up to 27 μ in diameter.

Chief Structural Characters.—Plant pubescent throughout, with long warty hairs and short capitate hairs. Bundles strongly developed and woody. Pith with simple and aggregate starch grains.

CHEMICAL COMPOSITION.—See tables under Forage Legumes.

SMOOTH PEA

Pisum sativum var. *arvense* Poir. = *P. arvense* L.

Fr. Pois. Sp. Guisante. It. Pisello. Ger. Erbse.

A description of the seed of the smooth pea is given in Volume II under Vegetables. Other details in that volume bearing on the forage crop are the general structure of the flower given under the head of the Wrinkled Pea and the general and microscopic structure of the immature pod of the Edible Podded Pea. Only the structure of the green plant (stem, petioles, rachis, tendrils, leaves, stipules, and flowers) is here considered.

MACROSCOPIC STRUCTURE. — Throughout, except for the flowers, the plant is smooth and covered with a bloom. The succulent *stem* and *petioles* are more or less four-sided, the tendrils, however, are well rounded. Large leaf-like *stipules* distinguish the pea from the soy bean and China bean. These are ear-shaped, sessile, and palmately veined. The pairs of oval or ovate leaflets commonly vary from one to four, and the tendrils, which are modified leaflets, from one to three and one-half, the odd tendril being terminal. Sometimes one of the upper pairs of leaflets is replaced by a tendril. Among the characteristics of the *flower* are the leaf-like calyx lobes, the wings grown to the keel, and the inwardly curved but not coiled style, bearded along the inner side and so flattened and folded along the under side as to form a groove.

MICROSCOPIC STRUCTURE.—When the plant is in flower its structure is as follows:

Stem, Petiole and Rachis.—Cross and longitudinal sections of the hollow stem and petiole show: (1) *epiderm* of long, parallel-walled cells interspersed with stomata, (2) *cortex* of rounded chlorophyl parenchyma, groups of collenchyma at the angles beneath the epiderm, and the endoderm (starch sheath) forming the inner boundary, (3) *crystal cells*, (4) *bast fibers* in groups, (5) *phloem* with well-developed sieve tubes, (6) *xylem* with spiral, reticulated, and pitted vessels, and (7) *pith* of large, empty, porous-walled cells lining the cavity and extending between the bundles to the cortex.

Tendrils.—Structure as in the preceding but less robust.

Leaflets and **Stipules** agree in having smooth *epiderms* of isodiametric or moderately elongated, somewhat wavy-walled cells and a mesophyl of typical chlorophyl tissue with palisade cells on the upper side of the leaf and crystal cells on the xylem (upper) side of the fibro-vascular bundles. The crystal cells differ in their position from those of the stem which adjoin the phloem side. Occasionally a few crystal cells

occur beneath the outer epiderm but they do not form a continuous layer. As may be seen in cross section, crystal cells often replace palisade cells on the upper side of the leaf over a bundle.

Flower.—In structure the lobes of the *calyx* are practically the same as the leaves except that delicate hairs of two kinds are present: (1) elongated, pointed, bi-cellular, the basal cell being very short, and (2) club-shaped with stalk of one or two joints and head of several cells usually in a row, although one or more of the cells may be divided by a longitudinal partition. Hairs of the first type occur at the tips of the lobes; those of the second type at the base on the inner epiderm. The epidermal cells of the *petals* have wavy walls, except at the base, and longitudinally striate cuticle. *Pollen grains,* up to 46 μ, are of the usual ellipsoidal, leguminous type.

Chief Structural Characters.—Plant glabrous to the naked eye throughout and covered with bloom, stipules large leaf-like (distinction from soy bean and China bean). Leaflets one to four pairs, with tendrils.

Epidermal cells of leaf isodiametric, very slightly wavy-walled. Crystal cells accompany vascular bundles. Calyx with delicate, long, pointed and short club-shaped hairs.

CHINA BEAN

Vigna sinensis (L.) Endl. = *Dolichos sinensis* L.

Ger. China-bohne.

The seed of the China bean, also known as the black-eyed bean and in the United States as the cow pea, is described in Volume II under Vegetables. As a forage legume, as well as a shell vegetable, the plant is of great importance in the southern states of the United States. Cow pea hay has high feeding value.

MACROSCOPIC STRUCTURE.—In general appearance the plant resembles the common bean, also the soy bean except that the stem is not hairy. The *stem* is strongly ribbed and in the lower part is hollow. Petioles and petiolules also have ribs, those on either side of the groove being extended as keels. Excepting the lowest pairs, which are simple on very short petioles, the *leaves* normally have three leaflets and are borne on long (often over 15 cm.) petioles. The *petiolules* of the side leaflets are about the same length as those of the lowest pair of leaves while that of the central leaflet is several times longer. The two lateral leaflets are unsymmetrical, the midrib being much nearer one edge than the other, making the whole more or less triangular with the two bottom

angles rounded and the terminal angle pointed. The central leaflet is symmetrical.

In addition to the midrib two prominent lateral ribs arise from the base. Because of hairs visible under a lens, the leaves are rough to the touch; other parts are practically smooth. Although small (10 to 15 mm.) the *stipules* are leaf-like.

The handsome *flowers* have white, cream-color, or violet petals, often cream-color when in bud and violet when the inner surfaces are exposed. Unlike the common bean but like the soy bean, the keel and style are not coiled but curved toward the standards. The calyx has five tooth-like lobes equaling or exceeding the tube. As in the hyacinth bean (*Dolichos*) the style is bearded on the inside but the stigma instead of being at the very tip is immediately below it, while opposite on the outside the style is extended as a short projection.

MICROSCOPIC STRUCTURE.—Stem, Petiole, and **Petiolule** consist of: (1) *epiderm* of elongated, parallel-walled cells, stomata, and occasional hairs both unicellular and capitate, (2) *collenchyma* forming a continuous layer, thickest in the ribs, (3) thin layer of *cortex parenchyma* containing chlorophyl grains, (4) *endodermis* (starch sheath), (5) *bast fibers* in groups, (6) *phloem* of the usual elements and occasional crystal cells, (7) *xylem*, and (8) *pith* of starch parenchyma from which thin medullary rays extend to the cortex.

The *unicellular hairs* are short and thorn-like, being broad at the base and curved at the point; the *capitate hairs* have multicellular heads with both cross and longitudinal partitions.

As in the soy bean the *starch* in the outer layers of the pith occurs as aggregates, the individuals of which form rounded humps, while in the central portion only individual grains are present. Both are, however, smaller than in the soy bean, the aggregates reaching 10 μ and the individuals only 4 μ.

Leaves.—Wavy-walled cells, stomata, and hairs make up both *epiderms*, the stomata being strikingly numerous on the lower epiderm. Thorn-like unicellular hairs and capitate hairs, such as occur on the stem, are present, the former, however, being limited chiefly to the ribs and veins on the lower surface. In addition to these, long, pointed hairs, up to 0.5 mm., with broad lumens and thick walls, are present on both surfaces. These, except for a very short foot cell, are unicellular.

As in the soy bean, crystal cells accompany the phloem elements.

The **Stipules** have the general structure of the leaves except that the *hairs* at the tip are especially long and *crystal cells* form a more or less continuous layer over the upper side of the fibro-vascular bundles.

Flower.—The absence of long hairs and the wavy-walled cells distinguish the *calyx* from the leaves. Numerous thorn-like and capitate hairs are present. The *corolla* is of the usual papillose type with color in solution. The *pollen grains* are rounded triangular (not ellipsoidal as in many legumes) and faintly reticulated, up to 80 μ in diameter.

CHIEF STRUCTURAL CHARACTERS.—Stem practically smooth; leaflets normally three on very long petiole; flowers white or violet.

Epidermal cells of leaf with wavy-walled cells, and short thorn-like unicellular, long thick-walled unicellular, and capitate hairs. Pollen grains rounded triangular (not ellipsoidal as in many legumes).

CHEMICAL COMPOSITION.—See tables under Forage Legumes.

SPRING VETCH

Vicia sativa L.

Fr. Vesce. Sp. Alverja. It. Veccia. Ger. Futterwicke.

In both Europe and America common or Spring vetch is used for green forage, hay, and silage, as well as for green manuring. The seed is described in Volume II under Vegetables.

MACROSCOPIC STRUCTURE.—The weak, four-sided *stem*, up to 1 meter, is more strongly angled than in the pea, also much more slender and not hollow. Usually the petioles are less than 5 mm. Normally the pairs of leaflets of the pinnate *leaf* range up to seven and the individual tendrils up to five. Although varying greatly the *leaflets* usually are less than 1.5 cm. long, slender, and obtuse, ending in a point about 0.5 mm. long. They exceed the joints of the rachis between adjoining pairs. Delicate hairs are evident to the naked eye on the leaves but are not noticeable on the stem. The *stipules* are minute, ear-shaped with pointed lobes.

MICROSCOPIC STRUCTURE. Stem.—As is true of the pea, its near relative, but not the soy and China beans of the *Phaseolus* group, the stem is not woody, collenchyma occurs only at the angles, and the fibro-vascular bundles are much less bulky than the intervening parenchyma. Unlike that of the pea the stem is hairy, the hairs being long (up to 1 mm.), about 15 μ broad, pointed, flattened, twisted, unicellular, with walls so thick as often to reduce the lumen to a mere line. The numerous twists in these hairs and at times the almost complete extinction of the lumen are highly characteristic. Short capitate hairs with multicellular heads are also present. Not being hollow, thin-walled empty parenchyma forms the central pith column.

Leaf.—Wavy-walled cells and stomata like those in the pea, but smaller, also hairs make up the *epiderms*. Hairs are more numerous than on the stem, but of the same types.

CHIEF STRUCTURAL CHARACTERS.—Plant pubescent, stem weak; pairs of leaflets usually up to seven and tendrils up to five.

Stem not woody; epidermal cells of leaf wavy-walled; hairs numerous, some long, unicellular, twisted, thick-walled, others short capitate.

CHEMICAL COMPOSITION.—See tables under Forage Legumes.

WINTER VETCH

Vicia villosa Roth.

Hairy or Russian vetch is grown in the British Isles and also in the United States, where it is known as Winter vetch because it endures the northern winters better than common or Spring vetch. Like the latter it is used for green forage, hay, silage, and soiling.

The seed is described in Volume II under Vegetables.

MACROSCOPIC STRUCTURE.—Hairs are conspicuous throughout. The leaflets are longer, often exceeding 2 cm., and the stipules are larger than in Spring vetch.

MICROSCOPIC STRUCTURE.—As in Spring vetch except that hairs are more numerous.

CHEMICAL COMPOSITION.—See tables under Forage Legumes.

JAPAN CLOVER

Lespedeza striata Hook et Arn.

Fr. Trèfle du japon. Ger. Japanischer Kleber.

This annual, long since well established in the southern United States, is well adapted for forage, hay, and soiling.

MACROSCOPIC STRUCTURE.—The *plant* is pubescent; the trifoliate *leaves* are small, each leaflet showing colorless veining, running parallel from the midrib, and ending in a beak; the *flowers* are pink, in clusters.

MICROSCOPIC STRUCTURE.—The unicellular hairs found on all parts of the plant are appressed, long, abut 15 μ broad, finely warty, with narrow lumen, and end abruptly in a sharp point (not tapering as in alfalfa and the common clovers). Crystal cells accompany the bundles. The walls of the lower epiderm of the leaf are thin and wavy.

CHEMICAL COMPOSITION.—See table under Forage Legumes.

FORAGE CACTI

(*Cactaceæ*)

The plants of this family are extensively used as stock food in southwestern United States and Mexico. Griffiths and Hare [1] have prepared an exhaustive monograph of the prickly pears (*Platopuntia*) and cane cacti (*Cylindropuntia*).

COMPARATIVE MACROSCOPIC STRUCTURE.—The joints of the fleshy *stems* are flattened in the prickly pears (wild varieties) and tunas (cultivated varieties of uncertain origin according to Griffiths and Hare), varying greatly in the ratio of breadth to length, the shorter and broader joints occurring in the tuna. In the cane cacti the joints are rounded. Although the numerous *leaves* are inconspicuous and disappear early, their positions are marked by the so-called areoles with tufts of hairs, barbed bristles, and, especially in the case of tuna, spines. The structure of the flower and fruit is considered under Prickly Pear, Volume II.

COMPARATIVE MICROSCOPIC STRUCTURE.—No data on the comparative histology of the vegetative organs are available. The fruit is described under Prickly Pear, Volume II.

COMPARATIVE CHEMICAL COMPOSITION.—Analyses have been made by Griffiths and Hare [1] of numerous samples of the stems and of the stems and fruit, representing species belonging to the genus *Opuntia* grown in Texas and adjoining regions. The table on the following page shows the average analyses of the stems of the prickly pear, of the cane cactus, and of a representative species of each, also the average of all analyses of stems and fruit of the prickly pear (94 samples) and of the cane cactus (66 samples).

Carbohydrates.—Hare[2] found that both *glucose* and *fructose* appear to be present in stems since the dried stems, previously extracted with ether, yielded to 95 per cent alcohol a levorotatory extract the osazone of which had the properties of glucosazone. A substance intermediate between mucilage and sugars was prepared from a 60 per cent alcohol extract of the dried stems. Before hydrolysis it was non-reducing. In

[1] New Mexico Agr. Exp. Sta. 1906, Bul. 60.

[2] New Mexico Agr. Exp. Sta. 1911, Bul. 80; Biochem. Bul. 1912, 2, 173.

Average Composition of Cactus Fodders (Griffiths and Hare)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Stems:						
Prickly pear	83.31	0.77	0.30	9.85	2.38	3.45
O. linheimeri	83.41	0.75	0.31	9.41	2.64	3.48
Cane cactus	75.91	1.62	0.45	13.45	3.90	4.42
O. fulgida	75.63	1.04	0.37	16.99	2.93	3.05
Stems and fruit:						
Cane cactus	78.47	1.41	0.63	12.30	3.59	3.61
Prickly pear	84.24	0.73	0.34	8.95	2.38	3.03

alcohol above 60 per cent strength the substance reprecipitated in flocculent form. The precipitate was soluble in water without forming a mucilage and on hydrolysis was dextrorotatory.

Mineral Constituents.—Griffiths and Hare[1] give complete ash analyses of 27 samples, representing nearly as many species, mostly consisting of stems, in percentages of the pure ash, a summary of which, recalculated, follows. Further recalculation to the original fresh substance for comparison with foregoing figures was not possible, owing to the lack of certain data, but a general idea may be obtained by assuming that the fresh material contained an average of 3 per cent of ash and recalculating the individual average results to that basis. The maximum percentages of silica (SiO_2), iron (Fe_2O_3), and alumina (Al_2O_3) occurred in a sample containing somewhat more sand than pure ash and were doubtless derived largely from adhering soil.

Ash Analyses of Stems of Prickly Pear and Other Cacti (Griffiths and Hare)

(Results in percentages of the pure (sand- and carbon-free) ash)

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl	CO_2
	%	%	%	%	%	%	%	%	%	%	%	%
Min.	3.76	0.00	28.28	2.77	0.14	0.00	0.06	0.22	0.34	0.29	0.30	27.75
Max.	20.02	2.25	47.57	15.43	1.46	1.72	1.95	2.04	3.43	7.10	6.18	39.72
Aver.	**11.69**	**0.58**	**38.35**	**8.85**	**0.44**	**0.45**	**0.51**	**1.04**	**1.36**	**1.25**	**1.84**	**33.66**

Attention is called by the authors to the high percentages of potash, lime, and magnesia in the ash. These bases combined as carbonate bear a direct relation to the alkaline soils of the desert regions in which the cacti grow.

[1] Loc. cit.

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